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I. METEORIC ASTRONOMY.

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BY awarding their Gold Medal to Signor Schiaparelli, in recognition of his researches into Meteoric Astronomy, the Astronomical Society may be said to have definitely sanctioned the conclusions which have been deduced from Schiaparelli's propositions. These conclusions are of such extreme importance, whether as viewed directly, or regarded in relation to the inferences which seem to flow from them, that they may be regarded as affecting our ideas respecting the present constitution as well as the past history and the future fate of all the orbs which people space. I propose to take the opportunity afforded by the recent action of the Astronomical Society to consider the position to which meteoric astronomy has at present been brought, and to point out the connection between the results established by Schiaparelli, and the subject of the solar corona, which has recently occupied so large a share of the attention of astronomers.

We need not consider here the history of the earlier meteoric theories. It would be difficult to show that the more correct ideas of the Greek and some of the Roman writers who have spoken of meteors were less purely speculative than the later view that meteors are mere phenomena of our own air, like lightning or the aurora. And although the theory that meteors are bodies which have been expelled from lunar or planetary volcanoes was discussed by mathematicians of eminence, yet it was not based on exact observation; so that the calculations of Laplace, Obbers, and others, serve rather to illustrate the skill of those mathematicians than to establish any conclusions of value.

We may begin, then, by considering the first important fact tending to prove the extra-terrestrial nature of meteors and shooting-stars,—the circumstance, namely, that meteoric displays occur commonly on certain days of the year.

It had been noticed in very early times that a display of shooting-stars nearly always occurs on the night of August 10. This being known in calendars as St. Lawrence's Day, the meteors which fall on that day have been called the tears of St. Lawrence. Among astronomers, however, they are more commonly called the Perseides, for a reason presently to be cited. Not so early, but still many years before the true theory of meteors began to be recognised, it was known that on or about the 12th and 13th of November, shooting-stars are commonly seen. When Humboldt, after witnessing the remarkable display of 1799, invited special attention to this circumstance, ancient records were examined, and it was found for several centuries this particular part of the year had been characterised by star-showers. "Time out of mind," says Sir John Herschel, "those identical nights more often, but sometimes those immediately adjacent, have been habitually signalised by such exhibitions."

It cannot be too often insisted upon,—since doubts are frequently expressed respecting the truth of the modern theory of meteors,—that this circumstance of periodicity suffices of itself to demonstrate the extra-terrestrial nature of these objects. There are no meteorological phenomena which recur persistently on August 10th and on November 13th; terrestrial volcanoes are not, then, exceptionally active; the moon on those dates may be in any part whatever of her orbit. The one circumstance to which phenomena recurring on a particular date can be held to point is the recurrent passage by the earth of a particular part of her orbit on that date. If we picture the earth circling around the sun in her wide orbit, once in each year, and remember that year after year as she crosses the particular point corresponding to August 10th, and again as she crosses the particular point corresponding to November 13th, her air is alive (as it were) with meteors, we at once see that this is because she comes across the meteors at those stages of her circuit. It is precisely as though a person who travelled continually on a certain road, noticed always at certain stages some peculiarities, such as heat or damp, or the like. He would be certain, after a few experiences of the sort, that the phenomenon was local in its nature,—peculiar, in fact, to the particular part of the road where it was recognised. So we, who voyage with the earth on a wide path round the sun, must conclude—must be absolutely certain—that the two particular regions of circumsolar space which we traverse on August 10th and November 13th are swarming with meteors.

Yet we cannot for a moment imagine that two clouds of meteors are persistently present in these two regions. Each meteor is as surely acted upon by the sun's mighty influence as this earth on which we live; and as surely as this earth, if brought to rest in any way, would be attracted towards the sun and fall upon his globe in about 64½ days, so every member of a meteor-cloud placed where the August and November meteors are encountered would in about the same time fall upon the sun and be destroyed.

It follows that the meteors must be in rapid motion, on a course keeping them clear of the sun's orb; and, moreover, that the place of those which pass away from the region traversed by the earth must be more or less continuously supplied by arriving meteors. In other words, the August and November meteors must form a more or less complete zone or ring. The degree of completeness of either ring must correspond to the regularity of the recurrence of star-falls on the dates corresponding to either system. If it frequently chances that the display is intermitted, either for a few years or for many years in succession, the inference will be that greater or less gaps mar the completeness of the meteor zone; whereas, if no year passes without a display of meteors belonging to a system, we must infer as at least probable that the meteor system forms a complete ring. Thus judged, the November system appears to be very far from forming a continuous zone; since the display is often omitted for more than twenty years in succession, and is seldom repeated during more than four or five successive years. The August system, on the contrary, seldom fails to produce a display of greater or less splendour.

So much may be regarded as demonstrated by the evidence already referred to. But to remove any doubt which may remain as to the justice of the inference that the August and November meteors are bodies travelling in a definite region of interplanetary space, there remains a test of a decisive nature.

Since, according to the hypothesis, all the August meteors are travelling along the same orbital zone, they must cross the earth's track on paths appreciably parallel, moving also with equal velocities. Now, regarding the earth with reference only to her orbital motion, we see that every meteor of the

August system which actually encounters the earth must reach the earth's globe from one and the same direction in space. If the earth were actually at rest, the meteors of this system would seem to fall like a shower coming from a definite quarter. This, indeed, might not appear to be the case to observers occupying a particular point on the earth's surface,—simply because the meteor-shower would be only partially discernible by him, and the circumstances would be such as to cause some illusion as to its origin and nature. But if we regard the earth as a whole,—and for a moment as a sentient being,—it will be obvious that, supposing she were at rest, she would seem to be exposed to a meteoric shower, many meteors falling upon her and yet larger numbers passing by her, but all appearing to come from the same quarter. But taking her orbital motion into account, we obtain a precisely similar result, only the direction of the shower becomes modified. The case may be compared to that of a railway carriage in a steady shower of rain; such a shower will appear steadily to proceed from one quarter of the sky whether the carriage is at rest or moving uniformly in a given direction. *Only* in the latter case, the part of the sky from which the shower seems to proceed will seem to be somewhat nearer to the point of the horizon towards which the train's motion is carrying the carriage. So with the earth passing through a meteor stream; the meteor-shower will seem to fall from one and the same part of the celestial sphere though the earth is travelling rapidly onwards; *only* the part of the heavens from which the shower seems to proceed will seem to be somewhat nearer to the point towards which the earth's orbital motion is carrying her than in the imaginary case of a fixed earth exposed to the continuous downfall of the meteors belonging to the August system.* But in either case the shower will seem to come from a determinate point of the star-sphere enclosing the earth on all sides.

Similar remarks apply to the November shower.

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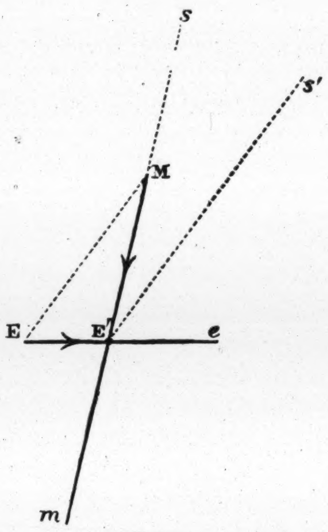
* In considering this matter we need not concern ourselves with questions of perspective, which, though commonly introduced to explain the subject, tend rather to perplex than to enlighten the learner. The case is exceedingly simple in reality:—

Thus, let E *e*, Fig. 1, be a small part of the earth's orbit at the place where any meteor system is encountered, and let M *m* indicate a portion of the meteor-orbit, M E′ being the course traversed by a particular meteor while the earth is moving along E E′, so that this meteor encounters the earth when she has arrived at E′. Then to the observer on earth, unconscious of the motion from E to E′, the course on which the meteor seems to arrive is obviously in the *direction* of a line from M to E, so that a line, *m* E′, parallel to M E is the seeming path of the meteor's arrival; and a point *s*′ on the celestial sphere, in the

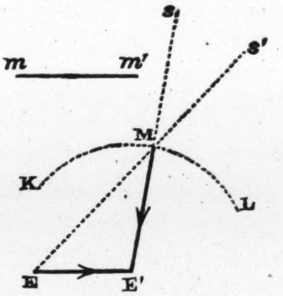
Plate I.

FIG. 1.



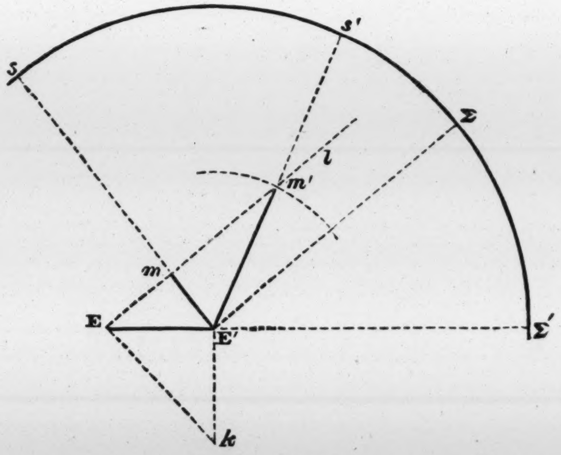
Illustrating the existence of meteoric "radiant points." (See page 140).

FIG. 2.



Illustrating the determination of the real course of meteors when their "radiant point" and velocity are known. (See page 144).

FIG. 3.



Showing how the arc on the heavens on which lies the true radiant of the August meteors can be determined by a simple construction. (See page 145).

Thus a test of the interplanetary nature of meteoric systems is at once afforded, and a test of a remarkably effective nature. For owing to the earth's rotation the star-sphere appears to rotate; and thus the part of the heavens whence a meteor shower seems to proceed is continually changing its place with respect to the horizon. *If*, notwithstanding this continual change of apparent place, a certain region of the stellar heavens continue to be that whence a meteor shower seems to come, the evidence is so much the stronger, because the test is applied under continually varying conditions.

In the case of both the meteor systems referred to, the test confirms the result already deduced. The meteors of each system seem to come from a definite region of the heavens,—or rather from a definite point of the star sphere. In the case of the August meteors this point lies towards the north-eastern part of the constellation Perseus, or, more exactly, the R.A. of the point is about 3 h. 24 m., its north declination about 55°. The November meteors appear to come from a point in the constellation Leo, between the stars ϵ and ζ of that constellation, or, more exactly, the R.A. of the point is about 9 h. 52 m., its north declination about 24°. These points are called the "radiant points" of the meteor systems, and because of the position of those points the August meteors are commonly called the Perseides, while the November meteors are called the Leonides.

It would be necessary to enter at this point on a consideration of the appearances actually presented by the August and November shooting-stars during any considerable display, if it were my present purpose to give a full account of what is known respecting meteors; but I wish at present to restrict the reader's attention as far as possible to the cosmical aspect of the subject.

The test here considered becomes, after it has served this

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direction E′ M′ indefinitely produced, is the point of the heavens from which that meteor seems to proceed. But the directions E′ E′ and M E′ are constant, and the proportion of E E′ to M E′ is constant; therefore the direction E M or E′ M′ is also constant. Hence every meteor of the system must appear to proceed from the point *s′* on the celestial sphere.

In reality every meteor of the system travels parallel to M *m*, and therefore is proceeding (at the time of crossing the earth's track) as if from a point *s* on the celestial sphere in the direction E′ M indefinitely produced.

Since the visible part of a meteor's course in our atmosphere is a straight line (approximately) directed from one and the same point of the heavens (so far as a given meteor system is concerned), it follows that wherever the observer may be, that course must appear to be such that if produced backwards it would pass through that part of the heavens.

particular turn, the means of proving the existence of other meteor systems which produce no recurrent showers, or no displays so persistently recurrent as to leave us assured of their being due to a true meteor system.

For, if many meteors seen on any night appear to radiate from a particular part of the heavens, we can infer very probably, though not quite certainly, that those meteors form a single group travelling all in the same direction. We can infer this, because we know that the observed event would certainly happen if the meteors form such a group; but we cannot be quite certain that one group only is in question, because two meteor groups crossing the earth's track at the same place might have different directions and velocities so adjusted that the members of each would seem to encounter the moving earth in the same direction. The unlikelihood of the coincidence renders the inference that a single group is in question so much the more probable. Now, if on the same night of other years,—or very nearly at the same date,—more meteors are seen to proceed from the same radiant point, we conclude that not a group but a system is in question, since at the very spot where meteors were really travelling in a definite direction in one year, other meteors are found following in their track in later years. Many millions of miles must separate the first set from those seen later; and the inference is, that along the whole range of those millions of miles there are meteors travelling with equal velocity in one and the same direction,—in other words, traversing a definite orbit region.

Applying this principle, the observers of meteors—Alexander Herschel, in England; Professor Newton, in America; Secchi, in Italy; Heis, in Germany; Quetelet, in Belgium; and Schmidt, in Greece; besides many others—have established the existence of seventy-six distinct meteor systems having radiant points north of the equator; while Neumayer, at Melbourne, and other observers, have noted many others having southern radiant points. It may be concluded safely that upwards of 150 meteor systems cross the earth's orbital track around the sun. Counting,—as resulting probably from the existence of corresponding but more important systems,—those falls of fireballs and of aërolites which have been observed to occur on or near certain definite days, and taking also into account the probability that some meteoric systems have hitherto escaped recognition, we may infer that some 200 systems of bodies traversing the interplanetary spaces pass close to the earth's orbit.

It does not follow, however, be it noted, that any one of these systems centrally crosses the earth's path, whether we regard that path as the elliptic line traversed by the earth's centre or as the elliptic ring traversed by the earth's globe. On the contrary, the chances are that the earth does not pass quite or even nearly through the *core* of any meteor system belonging to the solar domain.

Now when Schiaparelli commenced his inquiries, absolutely nothing was known about the extent of any one of the meteor systems traversed by the earth. To take the August and the November systems, it was known that one part of each lies near the earth's orbit. It was known also that the August system crosses the earth's track at a considerable angle, since even though the earth's motion brings the radiant point down (as it were) nearer to the point towards which the earth is making on August 10th (a point close by the star δ Arietis), the radiant is still some 37° from the ecliptic. It was known further that the November system travels much nearer to the plane of the ecliptic, and in a retrograde course (that is, meeting the earth), because the radiant lies within 10° of the ecliptic, and almost in the latitude of the point towards which the earth is travelling on November 13th (a point close by ψ Leonis). But nothing whatever was known as to the orbit range of either system—the major axis of the mean path of these meteoric families. For anything that had been shown to the contrary (setting aside as too unsatisfactory to be trusted the estimates of the velocities of the meteors while traversing our atmosphere), the part of the systems traversed by the earth might be the portion farthest from the sun, and the perihelion portion might be quite close to his orb; or the part traversed might be the perihelion portion, and the aphelion portion might have any distance whatever,—from a range little exceeding the earth's mean distance to one exceeding many times even the distance of Uranus or Neptune. This ignorance as to the meteoric orbit-ranges was necessarily accompanied by ignorance as to the real velocity with which they cross the earth's track, and this in its turn involved ignorance as to the true inclination of either system. Given the major axis of either meteor orbit, the real velocity of the meteors at the earth's distance would be known; and since the earth's motion is known in velocity and direction, the apparent direction of the meteor's motion being also known, the real direction of the meteoric motions follows at once. That this is so can readily be demonstrated.

Thus, let EE′ be taken to represent the earth's velocity in magnitude and direction, and let *mm′* represent in magnitude the real velocity of any meteors which seem to come in the direction s′ E; then we have only to describe the circular arc, KLM, around E′, with *mm′* as a radius, to obtain E′M the real direction of the meteor's motion. (Compare the note illustrated by Fig. 1). But this very construction shows us that so long as the real meteoric velocity, *mm′*, is unknown, we cannot tell the real direction, s′E, of the meteor's motion. The apparent velocity, ME, would indeed give us what we want (the point M in fact); but a meteor appears too suddenly and vanishes too quickly for exact reliance on any estimates of the velocity with which they traverse our atmosphere.*

Meteoric astronomy had reached this stage when Schiaparelli, who had already directed much attention to the subject, and had speculated somewhat boldly upon it, was led to compare the motion of the great comet of 1862 (No. III.) with that of the August meteors. Observing that this comet passed close to the earth's orbit on a course somewhat resembling that of the August meteors (on the assumption that they are moving with a velocity exceeding the earth's), he inquired whether the agreement would be found yet closer if the actual velocity of the comet where it passes close to the earth's orbit were assumed to be that with which the meteors are travelling when they enter the earth's atmosphere.

As this was the sole assumption made by Schiaparelli, it will be well to consider how far it affects the probability of inferences based on the coincidence actually recognised when this assumption has been made.

The real velocity of the August meteors cannot possibly exceed twenty-seven miles per second; since any greater, where they cross the earth's track, would give them a hyperbolic orbit, whereas it has been shown that they form a closed ring. Again, the real velocity cannot greatly fall short of the earth's, since otherwise the meteors of the system would appear to come from a point lying much nearer to that part of the heavens towards which the earth is travelling on August 11th than is actually the case.

Thus, let EE′ be a part of the earth's course on August

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* In any exact investigation of meteoric motions the influence of our earth's attraction, as well as the effects of the earth's rotation,—the former producing a real, the latter an apparent, change in the paths of meteors—must be taken into account. These circumstances do not, however, affect the general reasoning given above, and their effects are unimportant compared with those due to the circumsolar motions of the meteors and of the earth.

10th, Σ' the point on the heavens towards which she is travelling at the moment. Let E*l* be a line directed towards the radiant point of the August meteors, which lies about 40° from Σ'. Then E′*m* perpendicular to E*l* represents the least possible velocity for the meteors (where EE′ represents the earth's velocity). Coming from the direction of a point, *s*, in the heavens, with this velocity they would seem to radiate from Σ, E′Σ being drawn parallel to E*l*, since a meteor which was at *m* when the earth was at E would meet the earth at E′. Again, if we take E*m*′, equal to the diameter of a square of which EE′ is a side (that is equal to E*k*), this line will represent the greatest velocity a meteor crossing the earth's orbit can possibly have, if it is travelling in a closed orbit. This gives the direction, *s*′*m*′E′, along which an August meteor would actually travel, on the supposition that it has this maximum velocity. We may fairly assume that the meteors are not arriving on a course intermediate to *m*E′ and EE′, because then their relative velocity would fall much too far below the velocities estimated by Secchi, Newton, Herschel, and others.

From some point on the arc *ss*′ upon the celestial vault, therefore, the August meteors are certainly travelling; and with some velocity intermediate to the velocities represented by the lines *m*′E′ and *m*E′, where EE′ represents a velocity of 18½ miles per second. Moreover, the reader is not to suppose that the figure deals with hypothetical relations, and does not admit of being at once and definitely interpreted. Σ' represents a real point on the heavens, a point on the ecliptic close by the star δ Arietis, towards which, as already mentioned, the earth is actually travelling on August 10th. This point can at once be found on a celestial globe. Σ, again, is a known point, the radiant of the August meteors (already indicated), and about 39° from Σ'. It can, of course, be found on a globe, since its R.A. and declination have been given. Now let the end of a cord be held down on a globe at the point corresponding to Σ', and let the string be stretched over the globe across the point corresponding to Σ, so as to pass beyond Σ. It will indicate the position of the arc, *s*′*s*, on the celestial sphere. It will lie in a circular arc of which $\Sigma\Sigma'$ will represent 39°. And if we take points on it corresponding to

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* Because if *v* be the velocity, it can be shown that a body moving in a circle at a distance (*d*) from the sun, the velocity in a parabolic orbit will be $\sqrt{2}.v$, at a distance (*d*) from the sun. The earth's orbit is near enough to a circle to render this relation applicable; moreover, on August 10th, the earth is nearly at her mean distance from the sun.

s and *s′*; in other words, so that *s′* falls, as shown in Fig. 3, about 26° from Σ, and *s* 90° from Σ, we shall have on the celestial globe the arc *ss′*, along which the true radiant of the August meteors must lie. In other words, the August meteors are really travelling, when they cross the earth's orbit, as if from a point, this point lying somewhere on an arc about 64° long, and having the same place upon the star sphere that the string arc corresponding to *ss′* has upon the celestial globe.

Thus far there has been no assumption whatever. Moreover, without proceeding a step further, we can indicate a surprising coincidence which Schiaparelli was the first to recognise. The great comet of 1862 did beyond all question cross the earth's orbit from the direction of this very arc, *ss′*, that is, as if travelling from a point lying somewhere on this arc. The elements of the comet as determined by Oppolzer sufficed to demonstrate this. Thus, without any assumption whatever, it was proved that comet and meteors reached the part E′ of the earth's orbit along lines contained within one and the same sector of space, *s*E′*s′*.

But Schiaparelli had already indicated reasons for believing that the velocity of the meteors was nearly equal to the maximum (indicated in Fig. 3 by the line *m′*E′). What he now did was to point out that, granted this assumption only, the point whence the meteors are directing their course as they cross the earth's orbit lies close to *s′* (on the side away from Σ, of course), and that the point whence the comet was directing its course when it crossed the earth's track had appreciably *the same position*,—the comet's velocity, on this assumption, being identical with the meteor's velocity.

So that to sum up—*Assuming nothing, it was demonstrated that a comet and a meteor system, crossing the earth's track at the same spot, have directions certainly so far agreeing as to lie in the same sector in space—that sector having an angle of only* 64 *degrees;* and, *assuming for the meteors a velocity corresponding to what had already been assigned as the probable value of this element, the comet and meteors cross the earth's track on one and the same course and with identical velocities.*

This in reality indicates the full extent of the coincidence recognised by Schiaparelli. We must not go further, as some have done, and say that the orbit ring of the meteors was further found to coincide perfectly with the orbit of the comets. Still less must we (*as an additional proof of coincidence*) set the elements of the orbits side by side, as though the agreement of the two in respect of eccentricity, inclination, longitude of node and of perihelion, and so on, afforded so many additional evidences of coincidence. The fact is, that setting aside Schiaparelli's assumption as to the meteoric velocities, there is no agreement as respects any of these elements except the longitude of the node. There is a further coincidence not directly expressible in the ordinary orbit elements, and this coincidence, as indicated above, is sufficiently striking. It justifies, in fact, the assumption of equal velocities. Then this assumption being made, and leading to the coincidence of the actual direction of the two orbits where they cross the earth's, the exact coincidence of the two orbits, in all respects, follows inevitably,—since two bodies moving with equal velocities and in the same direction as they cross one and the same point in interplanetary space, must, by the law of gravity, follow identical orbits.

Or the matter may be otherwise expressed thus:—It follows from a discussion of the motions of the comet of 1862, that if the earth had been close by the place where her orbit is crossed by the comet when the comet actually traversed that place the comet's course would have seemed to be directed from the radiant of the August meteors. So much is *certain*. Schiaparelli inferred that the actual course of the comet as respects velocity and direction was identical with the course of the August meteors as they traverse the earth's orbit. We have already had occasion to consider the probability of such an inference, in speaking of the probable association between all the meteors which on any night appear to have the same radiant. The chances are great against the coincidence being accidental.

If I were here dealing with the history of meteoric astronomy, I should have to give a full account of the recognition of a corresponding resemblance between the motions of the November meteors and those of Tempel's comet (No. I., 1866). In particular, it would be desirable to discuss the share which Professor Adams took in the work. I notice with regret, by the way, that in Dr. Schellen's useful work on "Spectrum Analysis," the labours of Adams are left wholly unrecognised, while the comparatively less important researches of Schiaparelli, Oppolzer, Peters, and Leverrier, are pointedly referred to. This is not the place to supply the omission; but I may remark that if we set aside the labours of Adams, the only circumstance in which the discussion of the November meteors differed from that of the August meteors were *these:* there was, first, a reason for assigning a particular period to the November meteors, in the circumstance that great displays of these shooting-stars occur at mean intervals of about $33\frac{1}{4}$ years, and assigning a period amounted to assigning the velocity with which the meteors cross the earth's track; and secondly, the comet which agrees in its motions with the November meteors was dealt with separately, and the agreement only recognised after both orbits had been independently worked out. But the choice of $33\frac{1}{4}$ years as the period of the November meteors was still an assumption; and there were many eminent astronomers who regarded 34-33rds, or 32-33rds of a year as the more probable period. In any case, assuming a period, the task of determining the orbit from the observed position of the radiant was mere mathematical child's-play. But Professor Adams achieved a much nobler work. For he proved from the observed displacement of the node of the November meteors,—that is, of the point where the meteors cross the earth's track,—that the period *must* be $33\frac{1}{4}$ years or thereabouts. This was a task which none but a mathematician of the highest order could possibly have accomplished: and even to such a mathematician the task was a most laborious one. I do not say that Schiaparelli's case was not made out without Adams's assistance. The chances against the observed agreement as a result of accident were as great in the case of the November meteors as in the case of the August meteors, and the chances against both coincidences being accidental were therefore overwhelming. But Adams undoubtedly removed whatever element of doubt still remained; and, furthermore, if Schiaparelli's theory had never been started, Adams's work would of itself have sufficed to establish the true figure of the orbit on which the November meteors travel. It has seemed fitting to say thus much in recognition of the remarkable labours of our great English mathematician; but it need hardly be said that the value of Schiaparelli's ingenious researches and theories is in no way affected by the matter here referred to. The great importance of Schiaparelli's work consists in the light which it throws on cosmical problems of extreme interest and difficulty.

The fact, then, is demonstrated that two of the meteor systems encountered by the earth are so far associated with two comets as to travel on the same orbits. We may not unsafely infer that all the meteor systems encountered by the earth are in like manner associated with other comets. Nor is it very rash to assume that all comets are in like manner associated with meteor systems. Two cases may seem insufficient as a basis for such wide generalisations as these; but it must be remembered that they are the only two cases we have yet been able to deal with satisfactorily. It should be remarked, however, that some other comets have passed close by the earth's orbit, and that in several cases meteoric radiant points have been recognised which correspond fairly with the assumption that those comets are followed by meteor trains. However, as nothing has yet been proved respecting the relative length of meteoric trains following after comets, we cannot expect that the track of every comet should to any great distance be thus followed; and where the distance is relatively small, no evidence of the kind just referred to would be obtainable even a year or two (perhaps) after the comet had crossed the earth's orbit.

And here a word or two may be permitted on the question of the condition of comets freshly arriving on the scene of the solar system. It is assumed sometimes that the train of meteors already exists when the comet first comes within the solar domain. But, however this may be in other cases, there can be no question that in the August and November meteors, the train, at least the train we are acquainted with, must have been formed after the comet had become a member of the solar family. This will be evident if we consider how this last-mentioned result can alone come about. Take the case of the November meteors, the figure of whose orbit shows that the parent comet was forced to become a regular attendant of the sun by the disturbing influence of Uranus. Now, the circumstances under which a comet approaching the sun on a parabolic or hyperbolic orbit can be thus affected must be regarded as exceptional. The planet's influence must in the first place be very energetically exercised; in other words, the arriving comet must pass very close to the planet; for under any other circumstances the sun's influence so enormously outvies the planet's that the figure of the cometic orbit would be very little affected. Moreover, the planet's attraction must produce an important balance of retardation. The planet will inevitably accelerate the comet up to a certain point, and afterwards will retard it; the latter influence must greatly exceed the former. To show how greatly the comet must be retarded, it is only necessary to mention that the actual velocity of the November meteors, when they cross the orbit of Uranus, is less than one-third of the velocity with which Uranus himself travels; but their velocity at the same distance from the sun, when they were approaching him from some distant stellar domain, exceeded the velocity of Uranus in his orbit in the proportion of about 7 to 5. So that, roughly, their velocity at that distance has been reduced in the proportion of more than 21 to 5, or by 7-9ths of its original value. This is a reduction of about 4½ miles per second. Now Uranus could barely impart this velocity to a body approaching him from an infinite distance under his sole influence, and coming as near to him as the nearest of his satellites; but he could not impart so much additional velocity to a body approaching him (more rapidly of course) under solar influence. Now the velocity a body can impart it can also take away. Hence the retarding action of Uranus could under no circumstances account for the velocity of about 4½ miles per second, by which the motion of Tempel's comet must have been reduced, unless that comet passed closer to Uranus than his nearest satellite. Indeed, the maximum velocity which Uranus could impart to a body actually reaching his surface (and exposed to his sole influence in approaching from infinity) amounts only to 13·7 miles per second. Now the distance of Uranus's nearest satellite from the planet's surface is but about 84,000 miles, and Uranus traverses such a distance in less than five hours. So that the first and last meteors so influenced by Uranus as to be forced to part with a velocity of 4½ miles per second out of their actual velocity of about 6 miles per second, were assuredly not separated by a distance equal to a five hours' voyage, or in miles (at 6 miles per second) by so much as 108,000 miles. We may, indeed, safely infer that the actual distance was much less than this. For though all the meteors along a distance of 108,000 miles might have their velocity sufficiently reduced, yet in this case some of the meteors would have their velocity too much reduced, and would thenceforth pursue orbits differing very markedly from the orbits traversed by the remaining members of the system.

It follows, not merely as a probable inference, but I think as a demonstrated conclusion, that if the November meteors came originally into our system as a comet travelling sunward from infinity, then either that comet was very compact, or else Uranus captured only a small portion of the comet, the remaining portions moving thenceforth on orbits wholly different from the path of the November meteors.

There is no escape from this conclusion; for no other planet than Uranus can have brought about the subjection of this comet to solar rule.

One is almost led to doubt the extra-planetary origin of the November meteor system altogether, and to entertain the theory that the comet which produced it was in the first instance expelled from Uranus. We need not conclude, if we accept such a view, that the period named by Leverrier for the introduction of the comet into the solar system (A.D. 126) was necessarily the epoch of the expulsion of the comet by Uranus. The true epoch of this event may have been far more remote.*

This, at any rate, is certain, that if the comets belonging to our system have been introduced, as is commonly supposed, by planetary perturbing influences, then the actual number of arriving comets must have indefinitely exceeded the number captured in this way. For an arriving planet has a million chances of escaping for one of being captured,—so closely must it approach to one of the major planets if its motion is to be sufficiently controlled to cause it to become a permanent member of the solar system, with a perihelion near enough for the inhabitants of earth to recognise the comet, and with an aphelion not greatly beyond the orbit of the disturbing planet.

But be this as it may, the connection between meteors and comets remains an established fact, the existence of many comets in the solar system is a reality, and the fact that the earth encounters more than a hundred meteor systems cannot be disputed.

Now, if we consider what proportion of interplanetary space the earth really traverses, we shall begin to recognise one of the most surprising of the conclusions which are deducible from these demonstrated facts. If the earth were really, as she is sometimes pictured, a globe so large that in an ordinary picture of her orbit around the sun she would be presented, to scale, as a considerable sphere, there would be nothing very remarkable in the circumstance that on her course round the sun she should come into contact with many meteor systems. But when we are reminded that on so large a scale that the earth's orbit would be represented by a circle *ten feet* in diameter, the earth herself would be but about the 190th of an inch in diameter, so that the path her globe actually traverses would be represented by a circle 10 feet in diameter, and marked in with about as stout a stroke as the down strokes of the letters in this page, we see at once how minute a portion of sun-surrounding space this ring-orbit really occupies. Remembering that nearly all the meteor systems encountered by the earth travel on orbits largely inclined to the plane of the ecliptic, and, therefore, cross that plane in two spots (unequally distant in nearly every case from the sun), it will be seen how wonderful the circumstance is, that some 200 such spots should fall on the fine circle which forms the earth's true track in the ecliptic.

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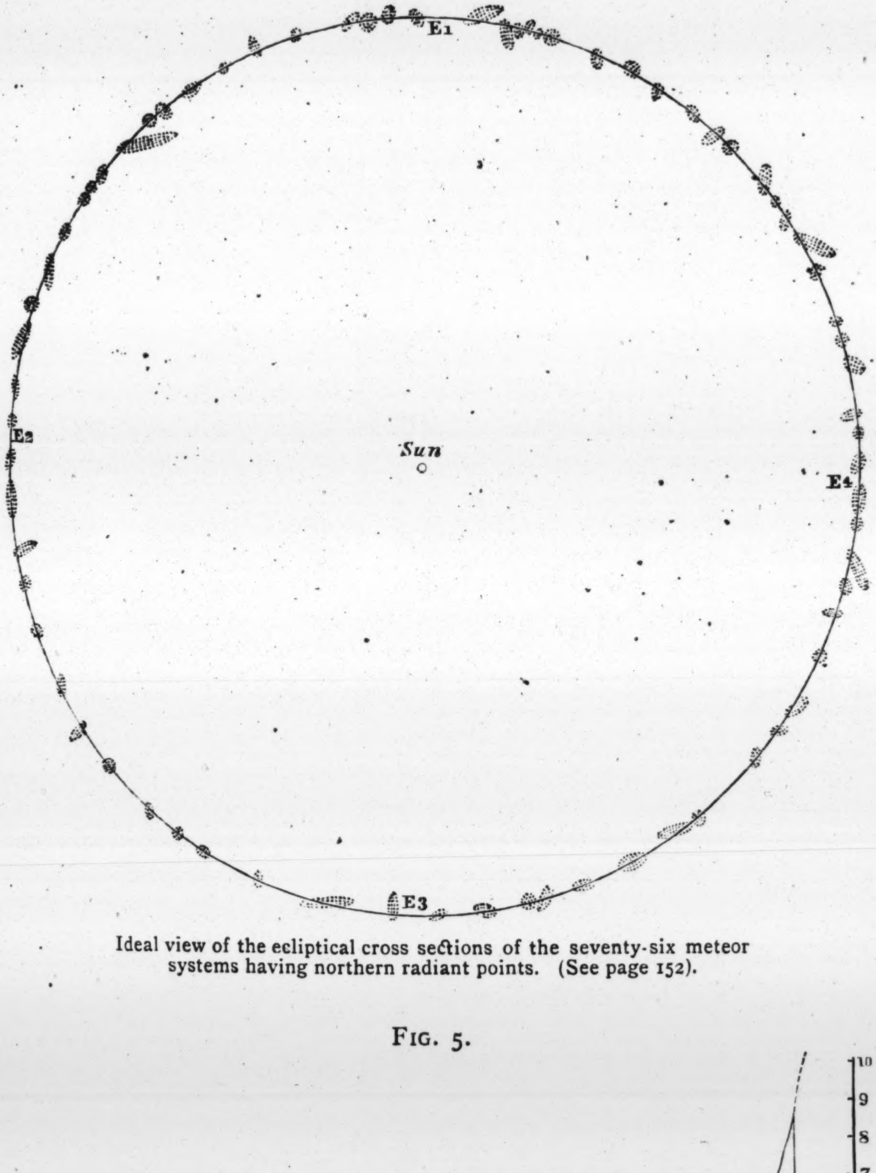
* It is also possible to account for the present position of the November meteor system by supposing that the encounter took place during that remote period when Uranus (according to the nebular theory) occupied a much larger region of space than at present.

Fig. 4 is intended to illustrate the remarkable nature of this circumstance. Here the circle $E_1 E_2 E_3 E_4$ represents the earth's path around the sun, E being the place of the earth at the time of the winter solstice. If we suppose the width of the circular line $E_1 E_2 E_3 E_4$ reduced to about a thirtieth part of its present value, we may regard this circle as picturing the actual shape of the region traversed by the earth. Now we know very little as to the real extent of the seventy-six meteoric rings traversed by the earth; but the cross section of each (regarded as cylindrical where crossing the ecliptic) may average perhaps a million or a million and a half of miles. According to the inclination of each and the actual direction of motion, the cross section with the ecliptic plane will be an ellipse of greater or less eccentricity, and having its longer axis in such and such a direction (which may be any whatever), with respect to the direction of the earth's orbit at the place of transit. These elliptical sections must, therefore, have some such arrangement as is depicted in Fig. 4. And it may be noted that for my present purpose, it is a matter of no importance whether the cross sections of the meteor rings be exaggerated or the reverse: since, on the one hand, if the cross sections are really larger, the importance of the several meteor zones is enhanced, but the circumstance that any given meteor zone is encountered by the earth is rendered *pro tanto* less surprising; while, on the other hand, if the cross sections are really smaller, we must infer that the number of meteoric zones is proportionately greater, to give the earth a reasonable chance of encountering so many systems. As to the shape of the cross section, it matters little what opinion we form; only if the real cross section is circular, the cross section on the ecliptic must have different oval shapes as shown in Fig. 4.

So far, then, as the meteoric systems which cross the ecliptic *descendingly* are concerned, we may fairly assume that their cross sections on the ecliptic form a scheme somewhat resembling what is pictured in the figure. It is known that southern skies are as plentiful in meteors as northern skies, if not more so; hence we must infer that as

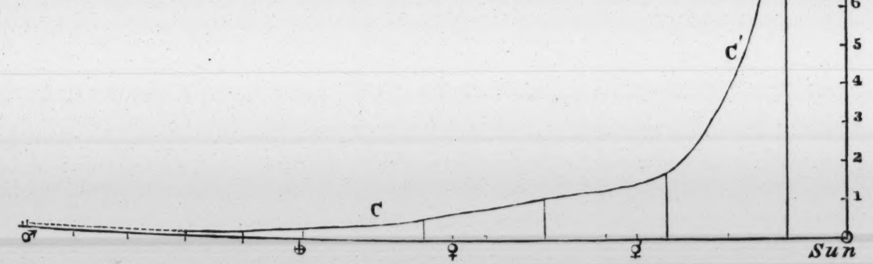
Plate II.

FIG. 4.



Ideal view of the ecliptical cross sections of the seventy-six meteor systems having northern radiant points. (See page 152).

FIG. 5.



Illustrating the increase in the richness of cometic distribution with approach towards the sun. (See page 154).

many cross sections as are depicted in Fig. 4 should be added (all overlapping the circle $E_1 E_2 E_3 E_4$) to represent the meteor systems which cross the ecliptic *ascendingly*, or from south to north. Moreover, an addition should be made for meteor systems which have hitherto escaped notice, as well as for a considerable number (perhaps nearly as many again as all yet mentioned) which, because they strike the earth's course on its inner or sun-illumined side, fall on the earth where day is in progress, and so escape recognition altogether. Add also the more sparse systems of "heavier metal" which produce fire-balls, and those others which have supplied the countless myriads of aërolites which are known to have fallen on the earth. I think it will be granted, that if all these circumstances were taken into acccount in Fig. 4, the earth's orbit, as there pictured, would be absolutely encumbered with the oval spots representing the cross sections of meteoric systems.

Now let it be remembered that each of the cross sections corresponds to a long stream of meteors, if not to a complete zone, the meteors travelling around orbits compared with which the orbit $E_1 E_2 E_3 E_4$ has utterly insignificant proportions. Imagine the seventy-six cross sections of Fig. 4 replaced by seventy-six curves carried on various arcs, even only across the circular space $E_1 E_2 E_3 E_4$ (that is, leaving out of account altogether those portions of the systems which lie farther away from the sun). Conceive the like done for about twice as many more systems corresponding to the orders just mentioned. This considered, it will surely begin to appear that the *sphere* of space around the sun, which $E_1 E_2 E_3 E_4$ will represent, is occupied in a remarkable manner by interlacing meteor-comet systems.

But it is certain that the earth's orbit is not clustered round with meteoric cross sections in the peculiar manner depicted in Fig. 4. That all those cross sections are there cannot be questioned, since so many northern meteor systems have been recognised. But outside and inside $E_1 E_2 E_3 E_4$ there must be meteor cross sections which the earth does not traverse. To suppose otherwise is as though a person who had traversed a certain route in a rain storm, should suppose that no rain had fallen to right or to left of his track. There is nothing in the earth's orbit to attract meteors. She herself has not the attractive energy necessary either to compel meteors to approach her track or to retain them against other attractive influences. It is only by chance, as it were, that her track lies thus through those special hundreds of meteor systems,—precisely as it is only by chance that such and such rain drops fall upon our illustrative traveller.

Hence, we have no choice but to suppose that the whole plane space within the circle $E_1 E_2 E_3 E_4$, as well as an immense plane extent of space outside that circle, is as richly bespread by meteor systems as we have seen to be the case with the circular track $E_1 E_2 E_3 E_4$—that is, much more richly than as pictured in Fig. 4. And here, too, we recognise the small importance of the extent we have given to the meteor cross sections in Fig. 4. Since, if the extent of each were smaller, we should have to cover the space within and without with greater numbers of these smaller cross sections, in order to account fairly for the fact that the earth's track lies across so many of them.

But when we remember, further, the connection which Schiaparelli has shown to exist between meteor systems and comets, we find a reason for believing that not merely a uniform degree of meteoric richness continues inwards from the earth's orbit up to or near the very place of the sun, but that a great increase of richness takes place as the sun's place is approached. Mr. Dunkin, in his valuable Appendix to Lardner's "Astronomy," presents the actual densities with which the perihelion points of observed comets are distributed throughout sun-surrounding space. He gives the following table:—

Distance from Sun in Millions of Miles.	Number of Perihelia.	Relative Cubical Space.	Density of Perihelia.
0 to 20	8·65	1	8·65
20 to 40	11·70	7	1·67
40 to 60	20·50	19	1·06
60 to 80	17·20	37	0·47
80 to 100	20·80	61	0·34
100 to 120	8·65	91	0·10

Here it will be observed that the increase of density with approach towards the sun is very rapid indeed in the sun's immediate neighbourhood. It is represented by the ordinates of the curve $c c'$ in Fig. 5, the dotted part of the curve being that inferred from the shape of the part which has been determined by observation. Moreover, it should be noticed that comets having their perihelia between 40 and 100 millions of miles from the sun are, on the whole, more likely to be recognised than those whose perihelia lie nearer to the sun.

We may fairly infer that the law indicated here for comets is that which holds also for meteor systems. Now let the following reasoning be carefully noted:—The members of a meteor system in travelling towards their perihelion open out their ranks, as it were, because travelling there with continually increasing speed, so that a given time difference between the place of two meteors corresponds to a continually increasing distance. We overrate this opening out in taking it as proportional to the square of the distance from the sun. Now the volumes of spherical spaces around the sun vary as the cube of the distance within which they are enclosed. Hence, *cœteris paribus*, the richness of meteoric distribution around the sun being proportional to $\frac{\text{number}}{\text{volume}}$, must vary inversely as the distance. Thus, a set or group of meteors, which at a distance of 90 millions of miles (about equal to the earth's), would spread with a certain degree of richness, would at a distance of 10 millions of miles be spread nine times more richly. Now, the above table shows that at a mean distance of 10 millions of miles (taking this as corresponding to the limits 0 and 20 millions,—an assumption very unfavourable to the argument) we have a density of perihelion distribution represented by 8·65 as against a density of only 0·34 at a distance of 90 millions of miles. Thus the density of perihelion distribution is about 25½ times greater at the former distance; and the actual mean meteoric density is about (9 × 25½, or) 230 times greater. Further, the illumination of these meteoric bodies at the lesser distance is 81 times greater, since this illumination varies as the square of the distance. Hence, under equally favourable conditions, the total quantity of light reflected from meteors within a given considerable space, at a distance of 10 millions of miles, exceeds that reflected from a set within an equal space at the earth's distance, in the proportion of 230 × 81 to 1, or upwards of 2000 times. Nearer to the sun than this still enormous distance the quantity of reflected light must be vastly greater; and if any meteors become incandescent owing to the great heat to which they are exposed, the total amount of light from these sun-surrounding regions must be yet further increased.

It should be noticed that the only assumption which has been made in the above reasoning is so far in accordance with the evidence actually obtained that any other assumption would have a considerable weight of probability against it. For if Schiaparelli's discovery has any cosmical importance at all,—and every one admits that it *has*,—it implies that all comets are followed by meteoric trains.

The reader has only to turn to Fig. 4 and to conceive the meteoric cross sections marked in all over the circular space $E_1 E_2 E_3 E_4$ with that degree of increasing richness *sunwards* which has been indicated above (remembering also, that as at present drawn, the figure shows less than half the real number of cross sections overlapping the earth's orbit), to perceive how richly sun-surrounding space must be crowded with meteoric systems. For not the ecliptic plane alone, but every plane through the sun, must be similarly intersected.

Albeit we must not forget that the meteor-systems severally are almost infinitely tenuous. It has been calculated by Professor Newton, of America, that even on the occasion of the great display of November meteors in America, in 1867, the portion of the system actually traversed by the earth contained only one meteor in 900,000 cubic miles of space: that is, in a cubic space nearly 100 miles long, broad, and deep, so that even taking into account the greatly increased richness close by the sun, we have not to deal with a real crowding of cosmical material; but, on the contrary, with an excessive tenuity, using this word to indicate the relation between the quantity of matter (however distributed) and the volume of the space within which it exists.

The reader will doubtless have surmised already the special purpose which I have had in view in the preceding inquiry. It seems to me that we have, in meteoric phenomena, as well as in the associated phenomena of comets, the explanation of some at least of the features presented by the solar corona. I cannot see how, on the one hand, the irregularities of structure which the corona presents at great apparent distances (up to two or three solar diameters, for instance) can be accounted for except by the theory that during eclipse the complicated network of meteor systems becomes discernible; nor, on the other, how the meteor systems can by any possibility escape recognition when a total solar eclipse is seen under favourable atmospheric conditions.

It has been supposed that, because I have advocated another theory in explanation of other features of the corona, I have abandoned the meteoric theory which I had formerly advocated. It is true that, in general, to advocate a new theory implies that a theory formerly held has been abandoned. But, in the present instance, this is not the case. The solar corona is a complicated phenomenon, and presents features which are severally due to different causes. Its irregularities may reasonably be attributed to one cause, while such features as the straight radial extensions, rifts, and so on may be (or rather must be) ascribed to another. It may be compared, in this sense, with the aurora. In explaining the general nature of this phenomenon, we may call into our aid the meteoric particles continually descending, in an irregular manner, through the upper regions of air; but in accounting for the auroral streamers, we have to consider processes taking place along straight (possibly along radial) lines.

It has been objected to the meteoric explanation, that the parts of the corona near the sun do not present the appearance which we should expect to recognise in meteors close by the sun, and are furthermore much brighter than we could expect even the innermost parts of the meteor region to appear. In this reasoning the circumstance seems to be overlooked that the meteor light which seems to come from regions close by the sun (assuming the meteoric theory to be true) does not come wholly, nor even chiefly, from meteors really so close to the solar orb. We look through a range of meteors two or three hundred millions of miles deep (taking into account space beyond the earth's orbit), and it is the combined effect of the light coming from the whole of this enormous range that we really recognise,—*not* in the corona, but in that proportion of the coronal light which is due to sun-illuminated meteors. The part of the range nearest to the sun may be the part most densely crowded and most brilliantly illuminated; but its extent is limited compared with that of the whole range; moreover, the meteors *there* situated turn but half discs (of reflected light) towards the earth, those beyond showing a much larger proportion of their illuminated halves. It is worthy of notice, indeed, that the farther half of the range supplies much the largest proportion of the light, on account of the greater fulness of illumination,—for in such a case as this, distance *per se* is an element which may be absolutely neglected.*

It need scarcely be pointed out that the spectroscope affords the best means for testing this question. If any considerable proportion of the corona's light is reflected from meteors, this portion of the light should exhibit a solar spectrum, though of great faintness; or, unless great light-gathering power were employed, a faint continuous spectrum would be seen. The zodiacal light, also, should exhibit a continuous spectrum if it represents the outer portion of the sun-surrounding meteor families. Until within the last few months the coronal light had been known to give a continuous spectrum as well as certain bright lines (or one bright line); and it had been stated that the zodiacal light gives a bright line spectrum. The first evidence was questionable; the second seemed opposed to the meteoric theory. But Janssen has examined the coronal light with the most powerful light-gathering means yet employed, and he recognises the solar dark lines in its spectrum. This evidence is unquestionable. And Liais, in the clear skies of tropical South America, has examined the zodiacal light and gets an infinitely faint continuous spectrum, so that what seemed a strong objection to the meteoric theory is removed. Let us pause, however. Liais has been charged with drawing an ideal picture of the corona during total eclipse, (his drawing by the way singularly countenancing the meteoric theory.) But it was ideal: how, then, shall Liais's evidence be trusted on any other subject? What, however, if it was not ideal at all; but simply *characteristic*, because Liais observed the eclipsed sun under singularly favourable conditions at his southern stations in 1858? This is precisely the inference fairly deducible from (or rather the conclusion forced upon us by) the evidence of the observers of the recent eclipse. Janssen speaks of special forms resembling those seen by Liais; observer after observer speaks of complicated structures within the corona; the photographs tell the same tale; and, lastly, the skilful artist Harrison, specially employed to ban the meteoric theory, has blessed it instead, his drawing as described by his friend Mr. Lockyer (so long the advocate of the atmospheric glare theory) "strongly recalling" the long suspected representation of the corona by Liais.

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* This at first sight may sound paradoxical; but it is strictly true nevertheless. The question is one of the apparent brightness of certain regions of the heavens, not of the total quantity of light received from given groups of meteors. A group of bright objects so far off as to appear like a cloud would preserve its *brightness* absolutely unchanged however far off the observer might remove. Its extent alone would diminish.

In conclusion, I believe little question can exist that a large proportion of these phenomena which have seemed most perplexing as well in the solar corona as in the zodiacal light, admit of being very readily explained when studied in the light of these theories of Schiaparelli's, which, after the usual term of doubt, have so recently received the sanction of the highest astronomical tribunal in Great Britain.

II. THE COPPER MINES OF CHILI.

By JAMES DOUGLAS, Quebec.

AS the produce of the Chili mines now regulates the price of copper all over the world, and all speculation as to its future price must depend on the probable future yield of these mines, their condition is a subject of prime importance to all interested in the copper trade. I have therefore thought that the following information, derived in great measure from personal observation during a visit made in the latter part of last year to several of the principal mineral districts of Chili, would not be unacceptable to your readers.

All the copper comes, with the exception of but a trifling quantity, from the coast range, and from within 30 miles of the sea, and nearly two-thirds of it from the three great mineral districts of Tomaya, Carrizal, and Chañaral. From the Cordillera of the Andes little is extracted, partly by reason of the drawbacks to mining at high elevations, where for half the year the mines are closed by snow, and where at all times hard work is impeded by difficulty of breathing, and partly by reason of the heavy freight to the coast. But apart from these obstacles, the copper deposits of the Andes have as a general rule been delusive, offering most tempting surface indications of great wealth, which further operations have not realised, while the ore is generally contaminated with other metals, whose separation is often difficult, and which depreciate the value of the copper. A small quantity of copper comes from the Cajon de Maïpu in the Cordillera of Santiago, and the Condes Mines in the Cordillera of the same province produce 200 tons or so of 23 per cent ore annually. The only Cordillera mines which augment notably the production of Chili and the Cerro Blanco—which though situated at the base of the Cordillera, a little south of the Copiopó, prove their relationship to the Cordillera mines by yielding arseniurets of copper and silver and lead ores; and the Esploradora mines of Mr. Sievert, in the Atacama Desert, 120 miles inland to the east of Pau de Azucar.

Proceeding from the south northward I shall briefly describe the several mining regions, and the quantities of copper they severally produce.

South of Santiago very little copper is found. A number of small mines are worked both in the Cordillera and in the coast range; but their total yield falls short of 1000 tons of fine copper annually. Crossing the line of 33° S. latitude there are upon the same parallel, extending from the coast to the Cordillera, a series of important copper deposits—beds and lodes. It includes the mines on both sides the Melon Valley and the Catemo and San Felipe Mines. The metals from the hills bounding the Melon Valley are simple copper ores; those from the Catemo and San Felipe mines yield a little silver. The San Felipe ores are a grey sulphide; but as a rule the lodes are narrow. An exception occurs in the Paral Mine on one of the Coimas group of lodes, where a lode of a yard wide yields on an average a 30 per cent ore; but as the mine is very badly worked, and the stopes are far below the foot of the shaft, twice as many men are employed in pumping as in breaking the ore. The mines throughout this whole district are languishing, and the total amount produced does not exceed 3000 tons a year. In all probablity this yield will not be maintained. Most of the ore is made into regulus and bars at smelting establishments in the Melon and at Catemo. In the San Felipe Valley Urmeneta and Errasuriz have attempted to use the peat—which is here abundant—for smelting, but as yet without advantage.

Travelling northward through the province of Aconcagua and the southern parts of the province of Coquimbo, one crosses chain after chain of hills, running E. and W., divided from one another by fertile, well-watered valleys. The hills are so saturated with copper that a *desmontes* or refuse heap enters as a conspicuous object into almost every bit of mountain scenery, and innumerable slag heaps in many a nook and corner mark the spots where furnaces smelted the ore from neighbouring mines till the hill sides, to the serious detriment of agriculture, had been denuded of timber, when mining and smelting together necessarily came to an end, on account of the heavy cost of transporting on mules the poor metals to the coast. Were the Coquimbo Railroad extended through Combarbola to Illapel, this region would again grow into some importance; but this is an event little likely of accomplishment.

When we reach the river Limari, near Ovalle, we come in sight of the Hill of Tomaya, the most southerly of the great Chili *minerales*. It is an isolated mountain, some 3 to 4 miles long, whose summit is 3000 feet above the plain, and 4200 above the sea. Its steep sides, furrowed with deep ravines, rise to a rugged top; where, viewed from a distance, the rocks seemed heaped pile on pile, as if, a stronghold of the Titans, the hill had been overwhelmed and buried by the missiles of an opposing host of giants—a string of white dots, the houses of the several establishments, about two-thirds of the way up, marks the position of the adits driven on the great lode, and long white streaks reaching far towards its base the enormous piles of *desmontes*, whose total amount probably exceeds 200,000 tons; and as one approaches nearer the hill looks as if a net had been thrown over it, the cords in their regular reticulations being the roads zig-zagging up the almost perpendicular sides.

There is not a spring of water on the hill, and the mines are so dry that they do not supply the needs of the establishments. The Piké mine alone has expended as much as 600 dols. a month, for water-jigging in the English still hutch is all the water concentration that can be effected.

The *minerale* contains three systems of N. and S. lodes:—

(1.) The most easterly lode runs near the eastern base of the hill. It yields very little copper.

(2.) The middle is the great Tomaya lode. It consists of twin veins, with a N. and S. strike and dipping west at an angle of 60°. They vary in distance from each other, being sometimes 5 fathoms apart, at others uniting to form large bunches. The eastern lode is left standing because too poor to work; but the largest stopes are at spots where the E. and W. lodes come together.

(3.) The third system of lodes is on the western slope of the hill. It was in working a mine on this lode that Mr. Urmeneta commenced amassing the fortune which the Piké mine has helped to swell; but the production from here has always been small compared with that derived from the middle lode.

This, the second group referred to above, crops out so near the summit as to form almost the crest of the hill. It runs as a twin lode for from 3 to 4 miles; but when its outcrop descends the N. and S. slopes of the ridge, it breaks up into a number of stringers, which diverge from the N. and S. course. The lode has not been traced as productive beyond the hill on either side.

It is therefore from this isolated hill that a great proportion of all the Chili copper came from the years 1860 to 1865; for Carrizal and Chañaral did not produce then what they do now.

The principal mines on the Maslir lode proceeding from south to north are:—

1. Almagro 2. Pizarro	Of 400 varas each in length along the strike of the lode. They were both rich at surface, but have fallen off in depth.

3. Piké or Pïque of 400 varas. This mine is and always has been the most productive on the hill. It is owned by Don José Tomás de Urmeneta, whose perseverance in prosecuting the work upon it during years of heavy expenditure and disappointment has been rewarded by raising him to the highest rank among successful miners, and by enabling him to confer vast benefits on his country; for Urmeneta was the first man to introduce into Chili first-rate hauling and other mining machinery.

For some fathoms below the outcrop the mine yielded carbonates and other oxidised ores. To these succeeded mixed purple and yellow sulphurets, which gave place to yellow only, about the 80-fathom level. This has become more and more mixed with specular iron and carbonate of lime the deeper the workings have been carried, so that the ore has become steadily poorer at the same time that the cost of extraction has increased.

A banded structure is very distinct in the lower levels. From the floor of the lode there is—

I. A clay selvage.

II. A layer of almost pure specular iron ore.

III. A layer of pure yellow sulphuret.

IV. The rest of the lode consists of yellow sulphuret mixed with quartz, carbonate of lime, and specular iron.

The yield of the lode from wall to wall is from 8 to 10 per cent, and its average size varies from 3 to 6 feet, but in places it bulges to vastly greater size. The great riches of the Piké were derived from some enormous stopes at about 60-fathom level, where the lode expanded to over 20 feet in width, and yielded a purple ore, which, as it came from the mine, averaged 30 to 35 per cent. It is supposed Urmeneta netted in one year at that time from this mine alone 1,100,000 dols.

The underground works consist of an adit level, run from the western face of the hill, which cuts the lode at about 60 fathoms below its outcrop. All above this level is now abandoned to *piqueneros* or tributers. The ore from below is hauled, by means of a Corliss engine and admirable machinery fitted with friction gearing, through three inclined shafts, which attain a depth of 80 fathoms below the end of the adit; but the lowest level is nearly 60 fathoms below this again. The ore is raised this last 60 fathoms on the backs of *Apéres* (ore carriers) and by hand winches. The lowest level of the mine is therefore about 200 fathoms from surface. The ladder shafts and all the galleries are inconveniently low and narrow. The stopes being very full and the ground insecure, the strain upon the timbering is tremendous, and at every yard you meet pieces bent or broken; and as the habit has been to repair the damage by simply adding others without removing the old ones, the passages have been undergoing a gradual diminution in size. At present little is being done to improve the condition of the mine, as the Lecaros Adit is just completed, and henceforth it is intended to draw the metals out by it. This work was commenced as far back as 1840 by Don Ramon de Caros. It enters the hill on its southern flank, at a spot where the lode was supposed to crop out. It was driven but slowly and irregularly till 1864, when Urmeneta bought the work already done and continued it more vigorously. It connects with one of the levels of the Piké at about 180 fathoms from surface. This level has been run under the neighbouring mine, the Chalaca, so that the total length of the adit is about 1000 fathoms, nearly half the length of the hill at that level. It is intended to sink a perpendicular shaft from the level of the adit, as the cost of keeping the inclined shaft in repair is found to counterbalance any advantage it offers. As it is expected that the cost of tramming the metals to grass will be much less than the present cost of raising them, it is intended through it to empty the stopes, many of the older of which are filled with 7 per cent ore, and to break down from the walls large quantities of metal deemed formerly too poor to mine. By drawing on these vast reserves the Piké will be able to keep up its supply for many years to come, even if the percentage of the ore from the workings should fall off. There are now employed in the mine 50 miners, but a larger number of tributers find employment in the upper workings.

Urmeneta is driving another adit from the same slope of the hill, but at a much lower level than the Lecaros. This is, however, being done only to secure certain setts which he owns to the west, on the dip of the lode, in obedience to the Spanish mining law, which requires a certain number of men to be employed on work tending to the development of the claim.

In this mine another hardship of the Spanish mining law in force in Chili is illustrated, though in this instance it redounds to M. Urmeneta's interest. His workings have undermined the neighbouring sett on the same lode. It is a small claim of only 200 varas in length by 100 varas in width. M. Urmeneta owns the claim to the west. Now as the lode dips W. at 60°, and the claims do not follow the lode, but are measured perpendicularly downward, M.

Urmeneta owns and is working the Chalaca mine in depth from the lower levels of the Piké. Even if he did not own the sett to the W. he might undermine his neighbour, for anyone may run into the adjacent mine, if his shaft be the deeper of the two, and break what metal he can, the only reparation to the injured man being one-half of the profits. The reason of these anomalies is that as Government levies an export duty of 5 per cent on all minerals, the law offers every facility for their acquisition. All mines belong to Government, which gives the first comer a title to them without charge, the first condition being that he works them, otherwise his title drops.

4. Chalaca mine of 200 varas, virtually worked out.

5. Rosario 6. San José	Both great mines, and deeper than the Piké; both yielded at the same depth purple sulphuret, and both have suffered the same decline in the produce of the ore as we have described in the Piké.

7. Dichosa 8. Guias 9. Morculago	The Dichosa once produced largely, but north of it the lode breaks up, and though tributers make profits very little regular work is done upon the branches.

The total production of these mines is about 1250 units daily. Of this about half comes from the Piké; and of this half may be said to be extracted from the regular workings below the adit level, and half by tributers from the abandoned stopes, or by ore pickers from the refuse heaps. Half of this yield leaves the hill either hand-picked or jigged to 25 per cent; the other half will stand at about 12 per cent. The scarcity of water is greatly felt and occasions great loss here as at all the other great mines. M. Urmeneta expects to drain from his adit enough to run a concentrating establishment near its mouth, in which beside a pair of Huot and Guyler's beautiful piston hutches there are twenty English hutches to be worked by hand and twenty by steam. He even hopes to run two buddles, but appearances hardly justify the hope.

Every mine has its crushing and concentrating establishment, in which generally a Blake's breaker, and one or more pairs of rolls and sizing sieves prepare the ore for English hutches. At the old Piké establishment Petherick hutches are used, but they do not give satisfaction. At the Rosario, Mr. Lipkin collects the concentrated stuff on the sieve, though the hutch is in other respects like and is worked similarly to the ordinary still hutch. Considering the scarcity of water, I think some form of Rittinger's *Pump-*

Sitze would answer, if slightly modified by the addition of endless chains to discharge the scimpings and concentrated stuff. All attempts at slime concentration have resulted unsatisfactorily. Krupp steel jackets are in general use for the rolls, and are admitted by all to be in every respect economical. A pair will remain in perfect working order for over a twelvemonth, neither pitting nor wearing unequally.

The *desmontes* are enormous. Those of the Piké are the largest and probably the poorest. They originally yielded 6 to 7 per cent, but having been picked over four times probably do not now contain over 4 per cent. Their size may be judged of by the fact that now in their fourth *bouleversement* they are completely overwhelming a good-sized village built on one of the shelves of the hill.

The hands employed in this *minerale* in every capacity number about 4000. As all ages and sexes work, this represents a population of about 8000. Urmeneta employs about 600, and as many more work on his property as tributers.

The rate of wages is for common labour 12 dols. a month, and rations worth 15 cents a day. Miners (native) 18 dols. a month, and rations of 15 cents a day. The same high rates approximately rule throughout all the mining regions of Chili. Cornishmen alone can be trusted with the timbering, and they are even better paid; so that it is evidently a mistake to suppose Chili owes her mining importance to cheapness of labour.

A railroad 36 miles long, connects the mines with the coast at Tongoy. It runs along an almost level plain to Cerillos, at the base of the hill, where, if the shareholders had been wise, they would have made the terminus. Thence it ascends by grades as steep as $5\frac{3}{4}°$, and curves as sharp as 187 feet radius, to the very mouths of the mines.

About 7 miles in a north-easterly direction, following the road, lies the monster lode of Panulcillo, forming also the crest of a ridge, along whose summit it rises like a wall when looked at from the south. The Tomaya people say that Providence placed these great deposits almost side by side that the ores of the one might serve to flux those of the other, but human perversity and English stupidity interfered to frustrate the kind intention.

The Panulcillo lode runs N. and S., and dips at first slightly to the W., and then perpendicularly. It is traceable, though barren, for over a mile to the S., and is visible as a distinct ridge a long way to the N.; but its productive portion is not very extensive. It has been opened—by an adit, driven on the southern extension of the lode, at a point nearly a mile distant from the workings, but the lode proving barren the work was dropped; by another adit, the San Gregorio, likewise to the south of the mine, but much closer, as it commences at the foot of the steep hill on which it exists; it is being pushed forward as the ground through which it cuts is improving; by open workings along the outcrop whence carbonates are still extracted; and by two E. and W. adits, through which the ore is now brought to surface by a steam engine in one case, and a horse whim in the other.

The two excavations, known as the North and South Mines, are separated from one another by a cross course, which does not displace the lode. In depth the lode seems to cut through it. The largest stope is in the North Mine, 400 feet long, 200 feet high, and in places 100 feet wide. The principal stope in the South Mine is almost as enormous. The workings more resemble a narrow rocky defile with steep sides, connected here and there by natural bridges, than the stopes of a mine. Paths are cut into the perpendicular cliffs, along which you climb by the aid of chains or a hand-rail, every now and then crossing by the arches left to support the walls. Into one of these immense caverns the light streams through an opening to surface in the roof, producing a most picturesque effect, which is heightened by the echoes of the miners' blows, and the plaintive chant with which they accompany their work.

The western wall of the lode is well-defined. On it lies a clay selvage; then a layer of galena of varying thickness, and carrying a little silver; then the main mass of the lode, which consists of a solid mixture of common iron pyrites, magnetic pyrites, and garnet, with copper pyrites and a small quantity of black-jack. Not more than 10 per cent of what is broken is thrown away in picking, and there is nothing left behind in the stopes. The yield of copper is now about 4·6 per cent, 1 per cent less than it was three years ago.

The cost of breaking, picking, and delivering the ore at the works is low, otherwise so poor an ore could not be worked. Spalling and picking is done for 1¼ cents a quintal metrico = 12½ cents per ton. At this rate good hands make 18 dols. a month. Driving is done by contract at 40 dols. a fathom. In stoping the principal cost is in fracturing the huge masses which are dislocated from the lode by each blast. It is intended to try dynamite for that purpose. In stoping the miner is paid 1 cent per inch for boring. English-men superintend the native barretero, indicating the spots where holes are to be made.

The picked ore is heap roasted at the mine, but very rapidly and imperfectly, as the smelting works are constantly ahead of the mine.

The smelting establishment was formerly at the mine's mouth, but has now been transferred to the railroad terminus in the valley, which bounds the hill to the south. The ore descends to it by an inclined tramway: for a certain distance the descent is steep enough to enable the full waggon to haul up the empty one; over the rest the hauling is done by horses. The cost of the ore delivered at the smelting works varies from 2·50 dols. to 3·00 dols. per ton.

There are now sent daily from the mine to the works 100 tons; formerly the daily yield was double that quantity. There has happily been more than a corresponding diminution in the number of hands employed, there being now at the mine and establishment 500 to 1300 formerly.

The smelting establishment consists of ten large reverberatories, and four blast furnaces, erected last year by Charles Lambert, jun. Only three of the reverberatories are running, and these exclusively on the finer ore unsuitable to the blast furnace. Each reverberatory smelts three charges daily of 90 cwts. each, and produces a 45 per cent matt, with the consumption of 1 ton of coal to 3·5 of ore. The 8-tuyere blast-furnaces smelt each on an average 50 tons daily, with the consumption of 1 of coke to 7·5 of ore. So fusible is the ore that the slags do not contain over 1-10th of 1 per cent of copper. The Panulcillo ore is mixed with about an equal part of richer carbonate before being smelted, a necessity that might be partly avoided by a more careful preparatory calcination.

The management in every department of the establishment is admirable; and had the same economy and prudence reigned in days gone by when the price of copper was better and the yield of the ore higher, immense profits, instead of heavy losses, would have been made. As it is, even in the past depressed state of the market, under Mr. Weir's superintendence, the mine has held its own, and now should make most profitable returns. It is the only property in Chili worked by an English Joint Stock Company with an office in England, and though it has suffered from the absence of that close scrutiny which is generally exercised only when a property is under the eye of its owners, now with Mr. Heatley in Valparaiso, and Mr. Weir at the mine, and a good price for copper, the enterprise ought to take a new lease of life.

A branch of the Coquimbo and Ovalle Railroad terminates near the smelting works. This railroad, in addition to the large yield from Panulcillo, used to carry considerable quantities of ore from Las Cardas, Cerillos, Tambillos, Andacolla, and other stations, all of which are now producing so little that the profits of the road have dwindled to nothing.

Mineralogically one of the most curious copper deposits in Chili is at Andacolla. A large bed of indurated magnesian clay is more or less permeated with a black sulphuret of copper. In drying the clay evidently cracked, and gave rise to innumerable narrow fissures, which became filled with the copper constituents of the bed. This has since undergone a very beautiful transformation in these veinlets near surface into silicates and carbonates; at greater depths into black oxide, red oxide, and metallic copper. In one of these miniature lodes one sees sometimes a central thread of undecomposed sulphuret, bordered by successive bands of black and red oxides and metal.

So soft is the ground that powder is rarely used in mining it. But the saving in this item is almost compensated for by the cost of timber. Stoping is out of the question. All the ore is extracted from galleries, which are timbered as fast as they are driven, and remain open for a fortnight or so, when the ground crushes in the timber tunnel, and the miner may commence driving again in the same spot.

The mines are situated in an arid plateau, famous from of old for its gold mines. The people, therefore, are accustomed to the use of the *batea*, or conical wooden dish of the gold washer, and therefore adopted it for the concentration of these ores.

The ore as it comes from the mine is sorted, the rich vein stuff separated from the bed stuff and the latter crushed to one-fourth of an inch. Women squatted round long tanks, wash the crushed ore in the *batea*, extracting less than one-half of its total contents, which, however, they raise to 25 per cent. A woman will wash 2 tons in twelve hours, extracting about 2 cwts. of concentrated stuff. When copper commanded a good price, even this wasteful method of washing (the only one practicable from water) gave most profitable returns; latterly, however, the pecuniary results have been less favourable, and the yield of the *minerale* has become insignificant.

The next mine worthy of notice is the Brillador, belonging to Charles Lambert. It is the nearest to the sea of all the Chili copper mines, being not over three miles in a straight line from the northern sweep of the Bay of Coquimbo.

This may be the reason of its having been more extensively worked than any other mine in the Indian and Spanish periods. Indian burrows—for they were nothing else—18 inches square, were often met in the older workings of the Farellon mine. From these narrow passages alone they extracted the ore, as they were never found to terminate in a larger excavation. Stone and copper hammers are still turned up in the refuse heaps, identical in shape and mode of attachment of the head to the handle with those from the Indian workings in the Lake Superior mines. There are three mines on an east and west lode, with a dip to the south, which can be traced for many miles, but is productive only at three points, where three huge dykes form the north wall of the lode. Adjacent to these dykes occur the chimnies of ore which have made the mines so wealthy.

The lode, like the great Tomaya lode, is a double vein, the richer being the southerly, the poorer the northerly. They appear to bulge alternately, but where they run together there such bunches occur as that from which Mr. Lambert, in 1847, is reported to have made 1,000,000 dols. profit. The northerly lode is left standing.

Of the three mines, work has always been most vigorously prosecuted on the first and third—the Farellon and Panteon mines; the intermediate mine, the Bronze, never having been very rich.

The Farellon is worked to a great depth. At surface it yielded carbonates, which gave place at once to yellow sulphuret without the interposition of the vitreous ore, which yielded the great riches of Tomaya. All these old workings are quite abandoned, and the ore is now extracted by an adit level, which strikes the lode at over 100 fathoms from its outcrop. From the end of this adit a shaft is sunk for 80 fathoms on the inclination of the lode, which carries in the lower levels from 1 to 2 yards of solid yellow ore. Although the ore is cut off to both the east and west by cross courses, there are so many fathoms of solid metal in view, that one cannot doubt but that if the Brillador were again actively worked, it would again assume its old rank among Chili mines. Neither Tomaya nor Carrizal can show anything to compare with the face of ore in the deepest workings of the Farellon. The realisation of Mr. Lambert's confident anticipation of a rise in the price of copper may induce him to work his famous mine with the force it deserves.

The Panteon Mine, at about a mile distant, once yielded handsomely; but the lode was lost long ago during Mr.

Lambert's residence in Chili, and all his skill and the expenditure of a couple of hundred thousand dollars failed to re-discover it. The Panteon is a huge quarry, from which from prehistoric times till to-day carbonated ores have been mined. The ores were, before Mr. Lambert came into possession, smelted principally in a neighbouring valley. The slag heaps were virtually heaps of regulus, as the smelter of those days utilised only the bath of metallic copper, which resulted from a single fusion of the rich carbonates, and was as ignorant of the mode of treating the rich slag as he was of calcining and smelting sulphuretted ores. To this day not only do the old *desmontes* of the Panteon supply the furnaces of the Compania (Mr. Lambert's Works, near Sirena) with carbonates, but the old Spanish slag heaps are being still overhauled.

Mr. Lambert built the first reverberatory furnace in Chili, and first smelted sulphuretted ores, which previously had been thrown aside as unserviceable. The Farellon Mine also was the first mine worked by stopes.

The dykes which, as before said, form the north walls of the productive portions of the lode, are themselves filled with little veins, which decrease in produce and size as they recede from the lode.

Fourteen leagues north of Sirena is the *minerale* of Higuera, several lodes of yellow sulphuret in a clayey gangue, of very intermittent yield. The ores are smelted at the mines and on the coast at the port of Totoralillos.

This is the last extensive *minerale* in the Province of Coquimbo. Soon after crossing the line of the Province of Atacama, and before reaching the river of Huasco, lies the *minerale* of San Juan, consisting like most other *minerales*, of a group of copper lodes and a number of mines which have been worked from time immemorial, but have never taken rank with the great Chili mines. The most important mines are those now worked by Messrs. Harker and Dickson, at Lebrar.

If the traveller crosses the valley of Huasco, at Vallenar, he enters the southern extension of the desert of Atacama, known as the plain of Algaroval. A range of hills separates this plain from the sea much as the coast range of Central Chili confines the great valley of San Fernando. In these hills at a distance of about six leagues in a straight line from the coast, has always been known to exist, but has been worked vigorously only within the last fifteen years, the great *minerale* of Carrizal, which sends more ore to market than even the hill of Tomaya.

There are, with a general direction of north-east and south-west, six lodes, only one of which, however, gives importance to the *minerale*. This is the *Veta Principal*. It forms the very crest of the hill of Carrizal, and then extends across the valley to the south-west, after which its direction is somewhat altered. On the hill it is wide, though broken, and there occur the richest mines. In the valley to the south-west it is narrower and more compact, yet yields well; but to the north-east, after the highest crest of the hill is passed, the mines are not producing profitably. On this lode there are 16 setts, yielding monthly about 4000 tons of 13 per cent ore; but most of this comes from six mines, the Mondaca, Remolinos, Portazuela or Bazanillo Alto, Toro, Cantado, and Santa Rita, all adjoining and situated on the crest of the hill or on its slope towards the valley.

To the north are two other lodes—the Veta del Agua and the Veta Malakoff, on both of which setts have been taken, though the lodes are unproductive, and shafts are being sunk by owners of mines on the Veta Principal in order to secure that lode in depth; another instance, in addition to that afforded by the Urmenita adit at Tomaya, of the detriment the law does to mining by involving the miner in useless expense in order to secure the permanency of his mine. The shafts being sunk to the north of the Mondaca mine should strike the Veta Principal—the nearer, the Margerita shaft, at 130 fathoms; the further, the Sebastopol shaft, at 165 fathoms. Unless these shafts strike good ore, showing that the run of poor ground now existing in the lower levels of the principal mines on the Veta Principal is local and partial, the *minerale* will rapidly decline, for none of the other veins show signs of great productiveness.

To the south of the Veta Principal and near at hand is a small lode, the Veta Santa Rosa, probably only a branch of the Veta Principal.

Then at a considerable distance on the southern slope of the hill are the Veta Greusa, and at its base the Veta Lachos. On the former ten setts have been secured, which yield perhaps 100 tons a month of 13 per cent ore, but only one is covering expenses; on the latter the same number of mines are being worked, and two only are returning profits.

The Veta de Verdiones, furthest to the south, is like the Veta Malakoff, large but unproductive.

The deepest workings are in the Portazuela Mine, whose shaft has reached a depth of 270 fathoms on the inclination of the lode, but the most productive mine is the Mondaca.

Its shaft attains a depth of 220 fathoms. An aneroid barometer indicated a vertical depth of 1000 feet. The total length of the shafts, wings, and levels is about 7 miles. There are employed on Company's account fifty *barreteros* (miners); and 150 tributers work on their own account in the abandoned upper workings.

The mine is supplied with good hauling machinery, worked by a 15 horse-power engine. In all the mines in this *minerale* great care is taken to condense the steam. So perfectly is this done, that at the Mondaca 5000 gallons monthly replace the loss in making steam and supply the wants of the establishment.

The mine is admirably worked. The levels are straighter, the shafts loftier, the timbering is better, and the exploratory work is further ahead of the stopes than in any of the Tomaya mines, thanks to the wisdom of the principal owner, Don Ramon Ovalle, and the skill of the manager, Mr. McAuliff. But the same is generally true of all the large mines in this region; due probably to the fact that they have been systematically worked only since the introduction of European methods of mining.

At surface and for some 60 fathoms below the lode is narrow; but here a branch, supposed to be the Veta Santa Rosa, falls into it, and it bulges suddenly to tremendous size. So at intervals it alternately contracts and expands: here diminishing to a yard in width; there bulging to six or seven times that size. The largest excavation in the Mondaca mine is 260 feet deep, 180 feet long, 45 feet wide. Twenty-one miners have worked abreast upon a solid face of ore. At about 120 fathoms from surface magnetic pyrites comes to preponderate so largely that for many fathoms the lode is left standing; but good yellow sulphuret of copper has reappeared in the central chimney of ore, and it is hoped the mine will resume its former richness. No banded structure is observable. The copper pyrites, mixed with quartz, magnetic pyrites, common pyrites, and a trace of blende, being mixed irregularly through the lode. A clay selvage occurs on the floor of the lode, and on the hanging wall a mineral resembling compact asbestos.

Although the lode is not producing as well as in the upper levels, the yield has not fallen off, so great are the reserves of good ore left to draw upon. The following table of the expense and production from 1862 to 1870, kindly furnished me by Mr. McAuliff, gives a good idea of the immense amount of work done and copper produced from a single large Chili mine :—

Date.	Annual Outlay.		Annual Production in Quintals Metrico.		Percentage.	Cost of Extraction per Quintal.
Year.	Dols.	Cents.	Dols.	Cents.		Cents.
1862	113,981	06	224,789	70	15½	51
1863	118,150	75	248,999	43	15½	48
1864	158,661	20	352,453	16	15½	45
1865	157,986	31	240,317	18	15	66
1866	145,449	13	261,590	44	15	56
1867	140,409	76	245,473	08	13$\frac{4}{10}$	57
1868	117,952	43	178,018	39	15	66
1869	119,329	37	203,000	13	13½	59
1870	159,702	00	266,000	00	13	60
	1,231,622	01	2,220,641	51		

The metrical quintal is equal to 1·971 English cwts.

About 4000 quintals monthly of rich oxidised ores are still extracted from the outcrop of the lode by tributers, consisting of carbonates and small quantities of black and red oxides, and oxychloride.

The Portazuela and Bazanillo Alto, owned by Messrs. Gonzales and Templeman, yields about as much. The same deterioration in depth has, however, there taken place as in the Mondaca.

Desmontes heaps cover the whole north-west face of the hill. They contain probably 300,000 tons of 3 to 4 per cent ore. The metal as broken from the lode probably carries about 6 per cent of copper, for it takes 3 tons to yield 1 ton of 13 per cent stuff, and the 2 tons thrown away contain about 3 per cent. It is found that the loss in picking when the ore is broken by a Blake, exceeds that incurred when hand labour is employed; hence the tributers refused to use it, but all the large mines find economy in treating the mine ores by it.

Some of the ore is sold to the smelting works on the coast, but most of it is heap-roasted and run into regulus at two establishments in Carrizal Alto, near the mines, and at two others at Canta del Agua, 5 miles from the mines, on the road to Carrizal Bajo.

The scarcity of water entirely precludes water-dressing at the mines. For a time a dressing establishment was run with success by Mr. Ovalle at the Canta del Agua, the water being obtained by cutting across the valley, and arresting the brackish water which filters through it from the plain of Algaroval towards the sea. The water flows in good sized streams into the eastern edge of that plain from the Andes, but is soon lost in the sand. In its long passage through miles of soil it becomes saturated with soluble mineral matters, and among others with salts of lime, which in the Canta del Agua form thin beds of limestone of great purity. The strata of soil in the Canta del Agua are :—

1 yard of	loose sand, pebbles, and salt.
½ yard of	sand, alternating with thin layers of carbonate of lime, which on removal rapidly reform.
	Sand and clay.
	Old river bed—a compact mass of shale and boulders of undetermined thickness, impermeable to water, and on which it flows.

Following the Canta del Agua into the Plain of Algaroval, and across it in a south-east direction, the railroad runs to Yirba Buena, 71 miles from Canta del Agua, and 99 from Carrizal Bajo on the Pacific. This station is at the foot of the spur of the Andes, where occurs the argentiferous copper lode of Corro Blanco. The lodes yielded at surface antimoniate of copper rich in silver; this changed at about 30 fathoms to argentiferous copper glance and galena, and the grey copper was replaced by copper pyrites, which is now the prominent product, though small quantities of the other ores are still exploited. The principal mines have been yielding largely and profitably for some years. Beside the principal lodes at Carrizal and Cerro Blanco, there are innumerable others worked on a small scale by two or more poor miners, the yield from all of which combined is considerable.

The next copper deposits worthy of note lie between Copiapó and Nantoko, in the hills bordering the river of Copiapó. They are exceedingly numerous and yield rich oxidised ores; but none of the mines are worked in the same systematic manner as those of Tomaya and Carrizal, nor do any of them promise to rise into great importance. On the contrary, partly from the unskilful way in which they have been worked, and partly from the high percentage required by the smelter (18 per cent), which no mine can continue to give after the rich outcrop has been removed, unless water dressing is possible, the yield of the Copiapó copper mines must continue to fall off.

Not so, however, that of the great mines back of the port of Chañaral, in the desert of Atacama. From Chañaral de las Animas, on the Pacific, the valley of the Rio Salado, in which water flows only after such exceptionally heavy rains as may fall twice or thrice in a century, runs almost due east and west for about 10 leagues to the mines of La Salado, and at about half that distance a valley enters from the south-east, in which is the *minerale* of Las Animas. From the Calita de las Animas, the former port of the *minerale*, the first shipment of copper from Chili is said by Dr. Philippi to have been made to Europe, in a whaler, in the year 1820. It came from the mines of Las Animas, shortly before discovered by Don Diego de Almeida. The lodes of La Salado were not discovered till about 1840. Since then both districts have been worked with very varying fortune, and perhaps more money has been lost than in any other Chili mines, owing to the cost of mining with high wages, dear provisions, total lack of water, and long carriage. A railroad, however, has just been opened from Chañaral to La Salado, so that the yield of both *minerales*, large as it is at present, will probably be notably increased. The metals are smelted in part at the port, in part at Mr. Sievert's establishment at Pan de Azucar, and partly sent south. Very little can be picked to a high enough grade for shipment to England.

A ride of five hours across the hills to the north brings one to the Mina Descubridora de Carrizalillo, owned by the estate of Mr. Watters, much of whose ore is rich enough to bear exportation from the port of Pan de Azucar to England. Watters's curious and rich San Pedro mine lies about 18 leagues in the interior, a little north of Tres Puntas, and at a still greater distance in the interior, some 40 leagues back of Pan de Azucar, is Sievert's Esploradora Mine, the last of a chain of mines between the coast and the Cordillera, worked by the same indomitable owner, who, in making such out-of-the-way mines pay without the aid of a railroad, has performed one of the greatest mining feats in South America.

All these mines together produce about 7000 tons fine annually.

Still further north, along the coast of Chili and Bolivia, as far as Tocopillo, are innumerable copper deposits, as at Paposa, El Cobre, and Cobijæ, which yield in abundance 5 to 10 per cent carbonates, oxychlorides, and other oxidised ore; but the distance from fuel, and the difficulty, in most instances, of picking the metal to a high percentage, have prevented their being profitably worked; though considerable quantities of metal are smelted at Taltal or sent south to Lota.

The *barilla* of Bolivia is native copper, which occurs disseminated in fine grains through a bed of sandstone, which extends probably from Corocoro, in Bolivia, to San Bartolo, in the northern part of the Desert of Atacama, in Chili, through an extension of 5½° of longitude. It was worked at San Bartolo by the Indians before the Spanish conquest; and since then one or two unsuccessful attempts have been made to re-open the mines, but the difficulty of transport through the desert has effectually frustrated them. From Corocoro, however, though the metal has to be brought on mule-back for 70 leagues to Tagna, and thence by rail to Arica, the port of shipment, some 2000 tons (fine) are annually exported, which is yet only half of what was formerly produced.

The foregoing are the main sources of supply of the copper, the news of whose fortnightly shipments are looked forward to by all copper miners and speculators so anxiously, as affecting so sensitively the price of the metal.

In round figures, the several mineral districts above enumerated may be said to yield as follows:—

	Tons.
Southern Chili, south of the Maipocho and Maipu rivers	1000
Catemo, and the districts of Petorea, Illapel, and Combarbola	3000
Tomaya	9000
Panulcillo, Cœrillos, Tambillos, and Andacollo	3000
Brillador Mine, Higuera, and small mines in the northern part of the Province of Coquimbo	3000
Peña Blanca, including San Juan and Lebrar	1000
Carrizal	8000
Cerro Blanco	2000
Copiapó	6000
Chañaral, and mines of Mr. Watters and Mr. Sievert	7000
Coast mines of Bolivia and Barilla	5000
	48,000

Are these several districts going to maintain their yield? Wherever any quantity of copper is produced by poor miners, working on their own small mines, there will doubtless be a notable falling off. Wages are daily rising. The Chili *peon* can get 1 dollar a day on the Peruvian railroads, and will therefore no longer work at home for 25 cents. Numbers of small mines, yielding each a few tons of picked ore annually, and which paid their workers—who were often at the same time owners—small wages, are being abandoned. Though the yield from each may be insignificant, their total production is by no means trifling. A great deal of the copper smelted at Guayacan and the Copiapó establishments is bought in small parcels of a few cwts. each: the Catemo district especially will suffer from this cause. On the other hand, improved methods of treatment and means of transport are leading to certain ores being treated which would formerly have been deemed valueless. An experiment is now being made on some very extensive beds of 4 to 5 per cent purple sulphuret near Tiltil, on the eastern slope of the coast range. They occur at an elevation of 5700 feet above the sea, and so perpendicularly above the nearest spot suitable for a concentrating establishment, that an aërial wire-road, which carries the ores from the mines, descends 2250 feet to the mill, with an average grade of 33°. There is during most of the year water enough for buddling, which is effected by eleven concave buddles, for which the ore is crushed by a Blake, four sets of steel-jacketed rolls, and a battery of twelve stamps. The Hunt and Douglas method is used for reducing the ore to metal in the wet way. It is a bold attempt, surrounded with many difficulties; but being under the management of Mr. Waring, one of the best mechanical and mining engineers in Chili, it bids fair to be remunerative. If the experiment succeed, other deposits of a like nature will be worked, and may supply the deficiency certain to arise from the causes just referred to.

Tomaya will doubtless produce less in the course of a few years; for the *desmontes*, which have for some years been yielding a considerable portion of its quotum, will hardly bear re-picking: the old workings, abandoned to tributers, are of course not inexhaustible, and the mines have invariably and steadily grown poorer in the deeper levels. Increased cost of production going on simultaneously with diminution in the percentage of the ore, must result sooner or later in a serious falling off. The facility of extracting poor ores, which the Lecaros adit may afford, may ward off the evil day for some years; but within the next decennial period the supply from this quarter must decrease, and that considerably.

Panulcillo sails so close to the wind that if copper falls it will inevitably fall; if copper stands at even 15s., there seems to be no reason why it should not live and prosper; for although the mine has been worked improvidently, and the necessities of the company have prevented any unproductive work being done, in the course of a twelvemonth or so of good prices the evil might be rectified and the supply of ore brought up to the old figure. No large Chili mine depends so entirely on a slight variation in the price of copper as Panulcillo. As at the late low price it managed to hold its own, a rise of 2s., or even 1s. per unit, would make the enterprise profitable.

No doubt the Brillador could yield more than it does. Higuera and the mines back of Peña Blanca taken all in all are as likely to fall off as to increase.

Carrizal, if the Veta Principal continues to grow poorer, has seen its best days; if, however, the new shafts now being sunk strike good ore, the *minerale* will produce more than ever. Judging from the experience of Tomaya, Carrizal, Catemo, and other mines, the Chili lodes steadily grow poorer in depth, the ore becomes more and more mixed with iron either as sulphuret or oxide; but as the deepest mine has not reached 300 fathoms in the inclination of the lode, it is unsafe to conclude that the deterioration will be progressive. Should it be so, Chili, even with the advantage of better prices, will not again bring up her production to that of 1869.

Cerro Blanco may continue producing as much as at present for some years to come. The Copiapó, suffering as it does from the increase in wages and the emigration of its population to the new silver *minerale* of Caracoles, will probably decline; but Chañaral, now that it has a railroad, may be expected to increase its yield. Bolivia is rapidly falling off in her production.

There is very little chance of any new mines of consequence being opened. A copper lode in a desert country cannot escape detection, more especially in Chili, where all the inhabitants are directly or indirectly interested in mines, and where professional mine hunters are constantly searching even the most arid and elevated regions for mineral. All the great lodes now worked, except, perhaps, those of the Salado and others in the Atacama desert, have been known and worked from time immemorial. There is, therefore, no probability of an increase in the production of Chili, but every probability of a steady decline. But that decline will not be sudden nor speedy. All the large mines have ore enough in sight, or reserves, to keep up the supply to nearly its present proportions for years to come. The great vacillations in the quantities shipped from month to month do not indicate a like vacillation in the production, which the railroad returns of ore or regulus carried to the coast from the different mines show to be comparatively constant. Mine owners and smelters are able in Chili as well as in England to hold large stocks in anticipation of a favourable turn in the market. Larger shipments than usual may be looked forward to as a result of the present favourable price,—since some large stocks are held, especially in the north. But advanced prices are not likely to increase the production to any great extent; for even if they rose sufficiently to justify ore being broken which has heretofore been left standing on account of its poverty, miners to do the work could not be found.

It is pretended that the new railroads penetrating the Cordillera, in Peru, will bring to market vast quantities of ore heretofore shut out by heavy freights; but it remains to be ascertained whether Cordillera copper mining in Peru will reverse the universal ill success which has attended it in Chili.

Copper Smelting in Chili.

As is well known, the condition in which the copper comes to England is not that of ore. Twenty-five years ago very little copper was smelted in Chili; whereas, in 1870, only 3·16 per cent was exported as ore, while 55·35 per cent was exported as bars and ingots, and 41·48 per cent as regulus. The previous review of the mines has shown how little ore of high produce is or can be obtained. It is therefore imperative that it be smelted as near the mine as possible. But the high price of fuel—the average cost of Chili coal delivered at any of the northern ports being 8 dollars a ton—renders smelting so expensive that only by the exercise of the greatest skill can it be profitably conducted.

Mr. Lambert, as already stated, erected the first reverberatory furnace in Chili about the year 1837, and by him were built the first extensive smelting works in the port of Coquimbo. But smelting received its greatest impulse from the operations of the Mexican and South American Smelting Company, whose large establishment at Herradura, near Coquimbo, was run from 1848 to 1857 with persistent loss. It, however, benefitted Chili by introducing Napier's method, which with certain modifications has continued to be that used in making bars.

There are throughout Chili about ninety furnaces making regulus, and about sixty calciners and furnaces making bars and ingots.

The two largest establishments are at Lota and Guayacan. The former is owned by a company, which likewise owns and works some coal beds in the neighbourhood. The steamers carrying coal north to the smelting works at the mines return laden with ore; hence the Lota Company, with coal of their own at hand, and being their own carriers of ore, can afford to smelt even poorer mineral than can the furnaces at the mines. The Guayacan works are owned by Messrs. Urmeneta and Errasuriz, and are among the largest in the world, running ordinarily seventeen triple hearth calcining furnaces, thirteen smelting reverberatories, and two refining furnaces. When in full blast the works can turn out monthly from 15 per cent ore, as regulus, bars, and ingots, equal to 1000 tons fine. The same proprietors have furnaces at Cerillos, at the foot of the Tomaya hill, where the poorer Tomaya ores are run into regulus, and other works at Tongoi, the port of Tomaya, where the rest of the Piké and some other Tomaya ores are run into regulus, and where also some bar copper is made; but most of the regulus of Cerillos and Tongoi is sent for further treatment to Guayacan.

On the other side of the neck of land which divides the Bays of Herradura and Coquimbo lies the town of Coquimbo, with the abandoned smelting works of Charles Lambert and of Don Ramon Ovalle and Co., and the active works of Edwards and Co., where such care is taken in the selection and smelting that their bars and ingots bring a better price in the English market than those of either Lota or Guayacan. They run into bars all the calcined regulus produced at the Compañia establishment of Mr. Lambert, situated on the Elqui river, just beyond the town of Sorena, and on the opposite side of the bay to Coquimbo. In the days of old activity there were here seven reverberatories running, each with its three-storied calciner attached; now only two are are running. At the Compañia are the only sulphuric acid works on the west coast. The acid is consumed in the manufacture of blue vitriol from the carbonate ores of the Panteon mine. The sulphate of copper finds a ready and profitable sale to the amalgamating works of the Copiapó.

But there are many other furnaces scattered throughout central and northern Chili, either at the mines themselves or at the nearest ports. The following are approximately the number of furnaces running regulus in the several districts:—

Lota	8
Catemo	6
Cerillos and Tongoi	6
Guayacan	13
Edwards	4
Brillador	2
Panulcillo	6
Higuera	4
Copiapó	5
Peña Blanca	5
Carrizal	19
Chañaral	5
Pan de Azucar	3
Tocopillo	4
	90

This number tallies with that obtained by estimating the number of furnaces from the work done. There were produced from January to July, 1871, in bars regulus 410,679 quintals of fine copper, which would represent about 876,111 quintals of 50 per cent regulus. As a furnace smelts about 300 quintals of 10 per cent ore into, say, 55 quintals of 50 per cent regulus daily, it would require eighty-seven furnaces running constantly to furnish the quantity above stated.

The proportion of coal consumed to ore smelted in making regulus is, at Panulcillo, in the reverberatories as 1 to 3·5; at Guayacan as 1 to 2·8; at the Compañia as 1 to 2·6; and at Carrizal as 1 to 2·6. The coal principally used is the Chili coal of Lota and Coronel, whose smelting value is about one-seventh less than that of English smelting coal.

At Caldera, the port of Copiapó, there is a smelting establishment in operation, and two up the river, one at Punta del Cobre and another at Nantoko, at both of which oxidised ores of 18 per cent are run into 62 per cent regulus; and argentiferous and auriferous regulus are made by smelting copper ores with the poorer class of silver and gold ores, and even gold tailings.

At Guayacan the operations are as follows:—A mixture is made of 15 per cent ore. Sufficient carbonates can generally be had to avoid the necessity of calcining any of the sulphuret. This mixture is run into a 50 per cent regulus.

In making bars the regulus is calcined dead, in accordance with Napier's recommendation; but at Guayacan it is, before entering the calciners, crushed between Cornish rolls to 1-8th of an inch, instead of being disintegrated in water, as is done at the Compañia.

The result of the fusion of the calcined regulus is a bath of 96 per cent metal, which is run into bars, and a rich matt of 70 per cent. This 70 per cent matt is then smelted into blister copper and a rich slag. The blister copper is refined in charges of 15 to 20 tons. Willow rods are used in polling, and in addition to anthracite dried aloe stems are thrown upon the bath of metal.

Mr. Francis, the smelter, to whose intelligent superintendence Guayacan owes much of its prosperity, says he can make a ton of refined ingots out of 13 per cent ore with 5 tons of coal.

III. NATURAL AND ARTIFICIAL FLIGHT.

IF ever the important problem of Artificial Flight is to be solved, it is reasonable to conclude that the same laws and forces which produce Natural Flight must be discovered and applied. Imbued with this belief, Dr. J. Bell Pettigrew, of the Royal College of Surgeons, Edinburgh, has made a series of elaborate inquiries into the structure and function of natural wings, and the peculiar properties requisite in artificial wings to produce artificial flight. Dr. Pettigrew has been engaged in these researches since 1865, and has carefully analysed, figured, and described, not only the movements of the wings of insects, bats, and birds, but he has also examined in detail the movements of a large number of animals fitted for swimming, such as the otter, seal, sea bear, walrus, penguin, turtle, crocodile, porpoise, fish, &c. By comparing the flippers of the seal, sea bear, and walrus with the fin and tail of the fish; and the wing of the penguin (a bird which is incapable of flight, and can only swim and dive) with the wing of the insect, bat, and bird, he has been able to show that a close analogy exists between the flippers, fins, and tails of sea mammals and fishes on the one hand, and the wings of insects, bats, and birds on the other; in fact, that theoretically and practically these organs, one and all, form flexible helices or screws, which, in virtue of their rapid reciprocating action, operate upon the water and air after the manner of double inclined planes.

Guided by these indications, he has especially directed his attention to the twisting flail-like movements of the wings of insects, of the flippers and tails of sea mammals, and of the fins and tails of fishes. These he finds all act upon the air and water by curved surfaces, the curved surfaces reversing, recriprocating, and engendering a wave pressure, which can be continued indefinitely at the will of the animal.

In order to prove that sea mammals and fishes swim, and insects, bats, and birds fly, by the aid of curved figure-of-8 surfaces, which exert an intermittent wave pressure, Dr. Pettigrew constructed artificial fins, flippers, and wings, which curved and tapered in every direction, and which were flexible and elastic, particularly towards the tips and posterior margins. These fins, flippers, and wings were slightly twisted upon themselves, and when applied to the water and air by a sculling or figure-of-8 motion, curiously enough not only reproduced the curved surfaces referred to, but all the other movements peculiar to the fins and tail of the fish when swimming, and to the wings of the insect, bat, and bird when flying.

To Dr. Pettigrew is due the discovery of the celebrated figure-of-8 or wave theory of flight which has been exciting so much attention on the Continent and in America. As early as 1867 Dr. Pettigrew gave his novel theory to the world in an evening lecture, delivered at the Royal Institution of Great Britain. On that occasion (*vide* Proc. Roy. Inst. of Great Britain, March 22, 1867) he pointed out the interesting fact that the wing was a screw *structurally* and *functionally*; in other words, that the wing when at rest was *twisted upon itself*, and that when it was made to vibrate or reciprocate it *twisted and untwisted figure-of-*8 *fashion*. The wing was shown to be as effective in water as in air, and the tail of the fish was represented as lashing from side to side, after the manner of an oar in sculling. In June of the same year (1867) he read a memoir on the subject to the Linnæan Society of London (Trans. Linn. Soc., vol. xxvi.), in which he described, figured, and compared the movements made by the fins and tail of the fish and the wing of the bird in flying and diving. These movements he showed were *reciprocating movements*, produced by helicoidal surfaces, which were mobile and plastic, and acted at a great variety of angles, so as to obtain a maximum result with a minimum of power, and, what is not less important, with a minimum of slip. The fish was represented as throwing its body into figure-of-8 curves in swimming, and the wing of the bird into similar curves in flying and diving—the figure of 8, when the animals were progressing at a high speed, being opened out or unravelled to form *first a looped, and then a waved track.** The following quotation from his memoir will explain the relation :—"The water and air are acted upon by curve or wave pressure, emanating in the one instance from the body of the fish, and in the other from the wing of the bird —*the reciprocating and opposite curves* into which the trunk and wing are thrown in swimming and flying, constituting, in reality, *a mobile helix or screw*, which, during its action, produces the precise kind and degree of pressure adapted to fluid media, and to which they respond with the greatest readiness." He also contrasted the screw formed by the wing with that at present employed in navigation; and showed that the latter, which is *rigid*, cannot be compared in point of efficiency with the former, which is *flexible and elastic*. The rigid screw of the ship is made to revolve, the one blade following the other in rapid succession, and all striking at a given angle which never varies. One blade, as a consequence, virtually performs all the work. From the fact that the one blade, which may be taken to represent the whole, moves in only one direction (it revolves round a given axis), it cuts out as it were the portion of water which corresponds with its area of revolution—a circumstance which greatly increases the slip, while it correspondingly diminishes the actual propelling power of the screw. It is otherwise with the screws formed by the tail of the fish and the wings of flying animals. These are *flexible and elastic*, and, when they are made to vibrate, they are also made to reverse the direction of the stroke, and reciprocate in such a manner that the stroke from above downwards, or from right to left, as the case may be, is made to produce a current, which being met by the wing or tail when it makes a counter stroke from below upwards, or from left to right, greatly augments the propelling power. This holds true of every successive stroke made by the wing or tail. This power is further augmented by the elasticity and flexibility which contribute to the continued play of the natural screw, and by the fact that the wing of the bird and the tail of the fish strike at a great variety of angles—this peculiarity enabling them to diminish the slip to a minimum and to increase the propelling power to a maximum. Dr. Pettigrew arrived at these results from a careful study of the extremities and travelling surfaces of a large number of animals fitted by nature for moving in water and air, and from numerous experiments with artificial fish tails, fins, and wings, which he made to vibrate with steam by a direct piston action. Continuing his researches, Dr. Pettigrew presented a second memoir on the subject to the Royal Society of Edinburgh, on the 2nd of August, 1870. This is published in vol. xxvi. of the "Transactions" of that Society, and in it he gives the details on which the conclusions arrived at in his first memoir were based.* Dr. Pettigrew shows that the wing acts as a kite both during the down and up strokes, and that it elevates and propels in either case—the rising and falling movements gliding by insensible degrees into each other to form one pulsation; that when the wing rises the body falls, and *vice versa;* that the wing, when the body of the flying animal is advancing in space, describes *a waved track*, the body describing a similar but smaller wave; that the wing is twisted upon itself when at rest and when in motion; that the blur or impression produced on the eye by it when made to vibrate rapidly is concavo-convex and twisted; that the under or concave surface of the wing, in virtue of its being carried obliquely forward against the air by the body, is effective during both the down and up strokes; that the wing rotates in the direction of its length and breadth as it rises and falls; that it reverses its planes more or less completely at every stroke; that it produces during the one stroke the currents by which it is elevated during the succeeding stroke—the wing literally rising on a whirlwind of its own forming; that the wing is movable and flexible as well as elastic, and capable of change of form in all its parts; that it is forced into waves during its action, and impinges upon the air as an ordinary sound does; that it produces a cross pulsation, the pulsatile waves running in the direction of the length of the wing and across it; that during its vibration it moves on the surface of an imaginary sphere; that the natural wing when elevated and depressed must move forwards; that the movements of the wing are comparatively slow at its root, but very rapid at its tip; that balancing is in a great measure effected by purely mechanical arrangements which operate independently of the will of the animal; that weight is necessary to horizontal flight; that the wing acts upon yielding fulcra; that a regulating power is necessary in flight, the wing being at all times thoroughly under control; that the wing in the bird descends as a long lever and ascends as a short one, the tip of the wing describing an ellipse as it does so; that the wing forms a parachute from which the body is suspended both during the down and up strokes; that the wing of the bird opens and closes as it rises and falls, and has a valvular action; that all wings are drawn towards the body and partly elevated by the action of elastic ligaments, &c.

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* Nearly two years after Dr. Pettigrew wrote, Professor Marey, of Paris, obtained similar results by the aid of the sphygmograph; and since then M. Senecal, M. de Fastes, M. Ciotti, and others have been labouring in the same field. These investigators have confirmed Dr. Pettigrew's original hypothesis, but, so far as we are aware, have added no new facts.

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* These memoirs extend to some 220 pages quarto, and are illustrated by nearly 200 original engravings and woodcuts.

Dr. Pettigrew's researches are dual in character. He first carefully describes and figures what is found in nature, after which he proceeds to demonstrate that the structures and movements which he has described and figured may be reproduced artificially. He takes, *e.g.*, a fish's fin or tail, and shows that during its action it lashes from side to side figure-of-8 fashion—the margins of the fin or tail throwing themselves into double or figure-of-8 curves as it does so. He then takes the wing of an insect, bat, or bird, and by placing the creature in certain positions the spectator can clearly trace the figure of 8 made by the tip and margins of the pinion. He, however, goes further. He points out how the tail of the fish and the wing of the bird may be imitated both as regards its structure and function. He, in fact, proves experimentally that the fish-tail and the wing have many features in common, and that propellers formed on the fish-tail and wing model are the most effective that can be devised, whether for navigating the water or the air. To operate efficiently on fluid, yielding media, the propeller itself must yield. Dr. Pettigrew has made this point very clear; and in this, we think, he has made a valuable discovery, for there can be little doubt that the propeller at present employed in navigation is faulty both in principle and application.

In the concluding part of his second memoir, Dr. Pettigrew explains that the inclined planes hitherto employed for water and air are *rigid*, whereas they ought to be *flexible* and *elastic;* that the old rigid inclined planes are made to attack the water and air at one angle and at a uniform speed, whereas they ought to strike at a great variety of angles and at a variable speed; that the inclined planes at present in vogue either advance in a straight line or revolve in one direction, whereas they ought to reverse and reciprocate to form vibrating *laminæ;* that the inclined planes at present employed draw a current after them, which, being never met, is consequently never utilised; that the artificial fish-tail and wing create the currents on which they mainly depend for support and progress by a peculiar reciprocating figure-of-8 action. Dr. Pettigrew's spiral elastic wings and flexible elastic screws will be hailed with satisfaction by all interested in the navigation of balloons. They possess advantages for this purpose which will necessitate their being universally adopted.

Dr. Pettigrew shows how an artificial insect, bat, or bird's wing may be made to vibrate with a wavy, continuous, reciprocating motion, devoid of dead points, the wing literally floating on the air. He points out how a properly-constructed artificial wing will, when elevated and depressed, inevitably dart forwards in a series of opposite curves, and that by altering the angle of inclination of the wing with the horizon, it may be made to fly upwards and forwards, horizontally, or downwards and forwards—flight, as he explains, being essentially not a vertical but a progressive and almost horizontal movement. He likewise gives directions as to the nature of the forces to be employed in driving artificial wings and propellers. The artificial wings and propellers, he states, are made to resemble the wing of the insect, bat, and bird, or the caudal fin of the fish. They are composed of flexible and elastic material, which varies in thickness, the thicker portions, which are consequently the more rigid parts, corresponding to the root and anterior margin of the wing and the root and lateral margins of the tail of the fish. When made to vibrate or reciprocate, the margins of the propeller formed on the wing and fish-tail model are thrown into double or figure-of-8 curves, from the fact that the propeller twists and untwists during its action. This twisting movement enables the propeller to evade and seize the water and air alternately with wonderful rapidity and power—the efficiency of the propeller increasing in a direct ratio to the velocity with which it is made to vibrate. By adding springs which antagonise each other, the propeller is lashed about with greater facility and with a more continuous play—a similar result being obtained by working the steam expansively.

The subjoined passages and illustrations from Dr. Pettigrew's memoirs will serve to elucidate the figure-of-8 or wave theory of flying, and cannot fail to be interesting to the reader, the more especially as they are strikingly original.

"*The Wing a Twisted Lever or Helix.*—The wings of insects and birds are, as a rule, more or less triangular in shape, the base of the triangle being directed towards the body, the sides anteriorly and posteriorly. They are also conical on section from within outwards and from before backwards; this shape converting the pinion into a delicately graduated instrument, balanced with the utmost nicety to satisfy the requirements of the muscular system on the one hand and the resistance and resiliency of the air on the other.

The neuræ or nervures in the insect's wing are arranged at the axis or root of the pinion, after the manner of a fan or spiral stair; the anterior one occupying a higher position than that farther back, and so of the others. As this arrangement extends also to the margins, the wings are more or less twisted upon themselves, and present a certain degree of convexity on their superior or upper surface, and a corresponding concavity on their inferior or under surface; their free edges supplying those fine curves which act with such efficacy upon the air, in obtaining the maximum of resistance and the minimum of displacement; or what is the same thing, the maximum of support with the minimum of slip. (*Vide a b* of Fig. 1, and *r g*, *s a*, of Fig. 1A.) . . . .

FIG. 1.

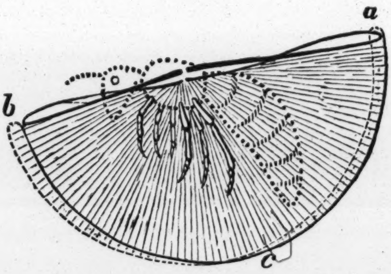
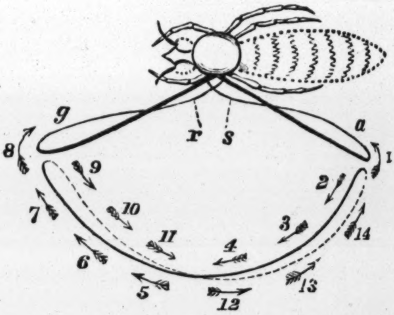


Fig. 1 repesents the oblique direction of the stroke of the wing in the flight of the insect (wasp)—how the wing is twisted upon itself at the end of the up (*a*) and down (*b*) strokes, and how the tip of the wing, during its vibration, describes a figure-of-8 track in space (*a*, *c*, *b*).

FIG. 1A.



Wasp seen from above and laterally. Shows how the wing twists upon itself during its action, the posterior or thin margin being inclined alternately forwards (*g*) and backwards (*r*) at the end of the down stroke, and backwards (*a*) and forwards (*s*) at the end of the up stroke. It also shows how the margins of the wing form figure-of-8 curves, and how the margins and tip of the wing form figure-of-8 tracks in space (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14).

All wings obtain their leverage by presenting oblique surfaces to the air, the degree of obliquity gradually increasing in a direction from behind forwards and downwards during extension, when the sudden or effective stroke is being given, and gradually decreasing in an opposite direction during flexion, or when the wing is being more slowly recovered preparatory to making a second stroke. The down stroke in insects—and this holds true also of birds—is therefore delivered *downwards and forwards*, and not as previous investigators have stated, vertically, or even slightly backwards.* . . . To confer on the wing the multiplicity of movement which it requires, it is supplied at its root with a double hinge or compound joint, which enables it to move not only in an upward, downward, forward, and backward direction, but also at various intermediate degrees of obliquity. . . . The wing of the bat (Fig. 2) and bird (Figs. 3 and 4), like that of the insect, is concavo-convex, and more or less twisted upon itself. The twisting is in a great measure owing to the manner in which the bones of the wing are twisted upon themselves, and the spiral nature of their articular surfaces, the long axes of the joints always intersecting each other at nearly right angles. As a result of this disposition of the articular surfaces, the wing may be shot out or extended, and retracted or flexed in nearly the same plane, the bones of the wing rotating in the direction of their length during either movement. This secondary action, or the revolving of the component bones upon their own axes, is of the greatest importance in the movements of the wing, as it communicates to the hand and forearm, and consequently to the volant membrane, or to the primary

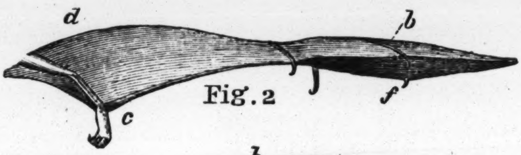


Fig. 2

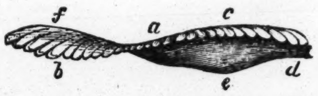


FIG. 3.

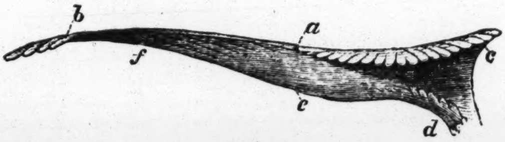


FIG. 4.

Fig. 2. Right wing of the Bat as seen from behind and from beneath. When so regarded, the anterior or thick margin (*d f*) of the wing displays different curves from those met with on the posterior (*b c*) or thin margin, the anterior and posterior margins crossing each other, as in the blades of a screw propeller.

Fig. 3. Left wing of Heron, partially extended, seen from beneath and from behind,—shows the spiral configuration and crossing of the anterior (*d e f*) and posterior (*c a b*) margins of the pinion; *e*, anterior axillary curve pointing downwards; *f*, posterior axillary curve pointing upwards; *c a*, posterior axillary curve pointing upwards; *b*, posterior distal curve pointing downwards. The posterior axillary and distal curve are reversed in complete extension (compare *b a c* of the present Fig. with *b a c* of Fig. 4.

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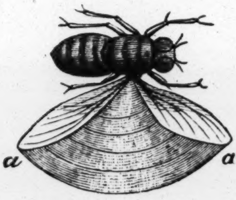
* The up stroke when the body is progressing at a high horizontal speed is delivered *upwards and forwards*, so that the wing invariably acts obliquely after the manner of a kite. Whether the wing is made to vibrate vertically or horizontally, it, practically speaking, in *progressive flight*, strikes *downwards and forwards* during the down stroke, and *upwards and forwards* during the up stroke.

and secondary feathers, the precise angles necessary for flight. It, in fact, insures that the wing, and the curtain or fringe of the wing, shall be screwed into and down upon the air in extension, and unscrewed or withdrawn from the air during flexion. The wing of the bat and bird may therefore be compared to a huge gimlet or auger, the axis of the gimlet representing the bones of the wing; the flanges or spiral thread of the gimlet, the volant membrane or rowing feathers."

"*The Wing Twists and Untwists during its Action.*—That the wing twists upon itself structurally, not only in the insect, but also in the bat and bird, any one may readily satisfy himself by a careful examination, and that it twists upon itself during its action I have had the most convincing and repeated proofs. The twisting in question is most marked in the posterior or thin margin of the wing, the anterior and thicker margin performing more the part of an axis. As a result of this arrangement, the anterior or thick margin cuts into the air quietly, and as it were by stealth, the posterior one producing on all occasions a violent commotion, especially perceptible if a flame be exposed behind the insect. Indeed, it is a matter for surprise that the spiral conformation of the pinion, and its spiral mode of action, should have eluded observation so long; and I shall be pardoned for dilating upon the subject when I state my conviction that it forms the fundamental and distinguishing feature in flight, and must be taken into account by all those who seek to solve this most involved and interesting problem by artificial means. The importance of the twisted configuration or screw-like form of the wing cannot be over-estimated. That this shape is intimately associated with flight is apparent from the fact that the rowing feathers of the wing of the bird are every one of them distinctly spiral in their nature; in fact, one entire rowing feather is equivalent—morphologically and physiologically—to one entire insect wing. In the wing of the martin, where the bones of the pinion are short and in some respects rudimentary, the primary and secondary feathers are greatly developed, and banked up in such a manner that the wing as a whole presents the same curves as those displayed by the insect's wing, or by the wing of the eagle, where the bones, muscles, and feathers have attained a maximum development. The conformation of the wing is such that it presents a waved appearance in every direction—the waves running longitudinally, transversely, and obliquely. The greater portion of the pinion may consequently be removed without materially impairing either its form or its functions. This is proved by making sections in various directions, and by finding that in some instances as much as two-thirds of the wing may be lopped off without destroying the power of flight. Thus, in the summer of 1866, I removed the posterior two-thirds from either wing of a blow-fly, and still the insect flew, and flew well. The only difference I could perceive amounted to this, that the fly, while it could elevate itself perfectly, flew in circles, and had less of a forward motion than before the mutilation. It had, in fact, lost propelling or driving power, the elevating or buoying power remaining the same. I took another blow-fly and removed the tip or outer third of either wing, and found that the driving power was the same as before the mutilation, while the elevating or buoying power was slightly diminished. These experiments prove that the posterior or thin elastic margin of the wing is more especially engaged in propelling, the tip in elevating. The spiral nature of the pinion is most readily recognised when the wing is seen from behind and from beneath, and when it is foreshortened. It is also well marked in some of the long-winged oceanic birds when viewed from before, and cannot escape detection under any circumstances, if sought for,—the wing being essentially composed of a congeries of curves, remarkable alike for their apparent simplicity and the subtlety of their detail."

" *The Wing during its Action Reverses its Planes, and describes a Figure-of-*8 *track in space.*—The twisting or rotating of the wing on its long axis is particularly evident during extension and flexion in the bat and bird, and likewise in the insect, especially the beetles, cockroaches, and others which fold their wings during repose. In these in extreme flexion the anterior or thick margin of the wing is directed downwards, and the posterior or thin one upwards. In the act of extension, however, the margins, in virtue of the wing rotating upon its long axis, reverse their positions, the anterior or thick margins describing a spiral course from below upwards, the posterior or thin margin describing a similar but opposite course from above downwards. These conditions, I need scarcely observe, are reversed during flexion. The movements of the margins during flexion and extension may be represented with a considerable degree of accuracy by a figure of 8 laid horizontally. . . . It may likewise happen, though more rarely, that the anterior or thick margin of the pinion may be directed upwards and backwards during the return or up stroke. I infer this from having observed that the anterior margin of the wing of the wasp (when the insect is fixed and the wings are being driven briskly) is not unfrequently directed upwards and forwards at the beginning of the down stroke, and upwards and backwards at the commencement of the up or return stroke. A figure of 8, compressed laterally and placed obliquely with its long axis running from left to right of the spectator, represents the movement in question. The down and up strokes, as will be seen from this account, cross each other, the wing smiting the air during its descent from above, as in the bird and bat, and during its ascent from below, as in the flying fish and boys' kite. The pinion thus acts as a helix or screw in a more or less horizontal direction from behind forwards, and from before backwards; but it has a third function—it likewise acts as a screw in a nearly vertical direction from below upwards. . . . If the wing (of the larger domestic fly) be viewed during its vibrations from above, it will be found that the blur or impression produced on the eye by its action is more or less concave (Fig. 5, *aa'*).

FIG. 5.



Blur or impression produced on the eye by the rapidly oscillating wing of the Blow-Fly when the insect is progressing at a high speed. Seen from above and from the side *a a'* represents the waved track made by the wing in progressive flight.

This is due to the fact that the wing is spiral in its nature, and because during its action it twists upon itself in such a manner as to describe a double curve,—the one curve being directed upwards, the other downwards. The double curve referred to is particularly evident in the flight of birds from the greater size of their wings (Fig. 4, *ba*, *ac*). The wing, both when at rest and in motion, may not inaptly be compared to the blade of an ordinary screw propeller as employed in navigation. Thus the general outline of the wing corresponds closely with the outline of the propeller, and the track described by the wing in space is twisted upon itself propeller fashion. The great velocity with which the wing is driven converts the impression or blur into what is equivalent to a solid for the time being, in the same way that the spokes of a wheel in violent motion, as is well understood, completely occupy the space contained within the rim or circumference of the wheel. . . . From these remarks it will appear that not only the margins, but also the direction of the planes of the wing, are more or less completely reversed at each complete flexion and extension; and it is this reversing, or screwing and unscrewing, which enables the wing to lay hold of the air with such avidity during extension, and to disentangle itself with such facility during flexion,—to present, in fact, a more or less concave, oblique, and strongly resisting surface the one instant, and a comparatively narrow, non-resisting cutting edge the next. The figure-of-8 action of the wing explains how an insect or bird may fix itself in the air, the backward and forward reciprocating action of the pinion being so regulated as to afford support, but no propulsion."

"*The Wing, when Advancing with the Body, describes a Waved Track.*—Although the figure of 8 represents with considerable fidelity the twisting of the wing upon its axis during extension and flexion, when the insect is playing its wings before an object, or still better, when it is artificially fixed, it is otherwise when the insect is fairly on the wing, and progressing rapidly. In this case the wing, in virtue of its being carried forwards by the body in motion, describes an undulating course."

FIG. 6.

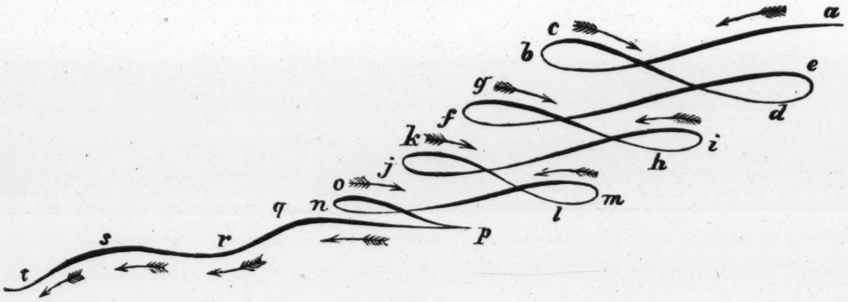
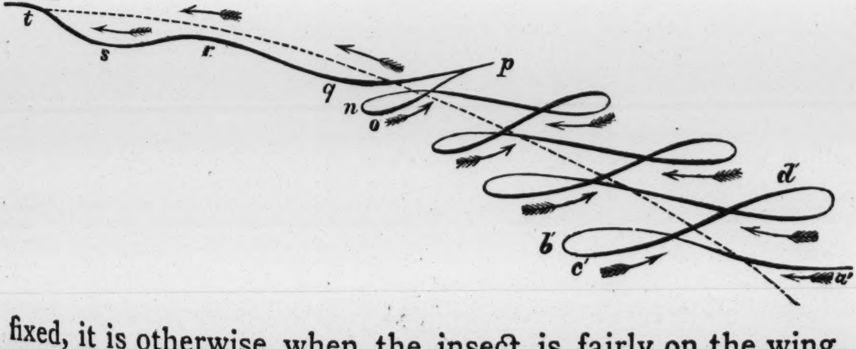


FIG. 7.



"*How the Figure of* 8 *is Unravelled, and becomes a Waved Track.*—When the insect flies in a horizontal direction, and the speed attained increases with the duration of flight, the wing reciprocates less and less perfectly, because the figure of 8 sweeps described by it are converted into a looped and then a waved track, as represented at *a b c d e f g h i j k l m n o p q r s t* of Fig. 6; the corresponding looped waved track due to recoil being shown at similar letters of Fig. 7. The body of the insect is carried along the curve represented by the dotted line of Fig. 7.

The waved track formed by the ascent and descent of the wing in the progressive flight of the bat and bird is originated in a similar manner, but in this case the figure-of-8

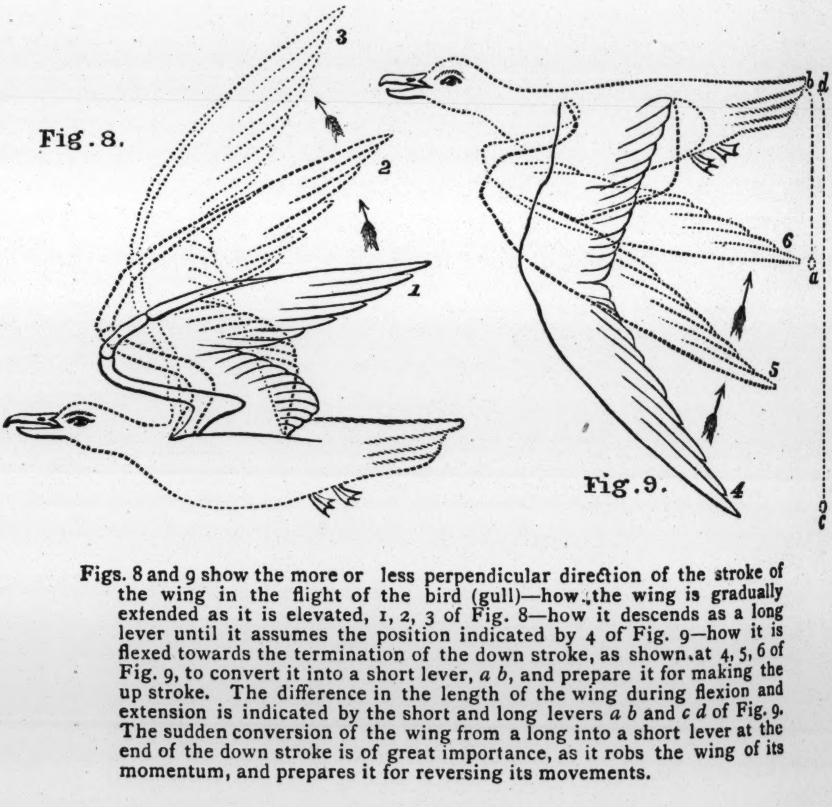


Fig. 8.

Fig. 9.

Figs. 8 and 9 show the more or less perpendicular direction of the stroke of the wing in the flight of the bird (gull)—how the wing is gradually extended as it is elevated, 1, 2, 3 of Fig. 8—how it descends as a long lever until it assumes the position indicated by 4 of Fig. 9—how it is flexed towards the termination of the down stroke, as shown at 4, 5, 6 of Fig. 9, to convert it into a short lever, *a b*, and prepare it for making the up stroke. The difference in the length of the wing during flexion and extension is indicated by the short and long levers *a b* and *c d* of Fig. 9. The sudden conversion of the wing from a long into a short lever at the end of the down stroke is of great importance, as it robs the wing of its momentum, and prepares it for reversing its movements.

loops are disposed more vertically, because of the more vertical direction of the stroke as represented at 1 2 3, 4 5 6 of Figs. 8 and 9.

The unravelling process is shown *a b c d e f g h i j k l m n o p* of Fig. 10; the completed wave-track being seen at *s t u v w* of the same figure."

"*The Natural Wing, when Elevated and Depressed, must move forwards.*—It is a condition of natural wings, and of artificial wings constructed on the principle of living wings, that when forcibly elevated or depressed, even in a strictly vertical direction, they inevitably dart forward. This is well shown in Fig. 11."

If, for example, the wing is suddenly depressed in *a vertical direction,* as represented at *a b*, it at once darts downwards and forwards in a curve to *c*, thus connecting the vertical down stroke into *a down oblique forward stroke*. If, again, the wing be suddenly elevated in a strictly vertical direction, as at *c d*, the wing as certainly darts upwards and forwards in a curve to *e*, thus connecting the vertical up stroke into an *upward oblique forward stroke*. The same thing happens when the wing is depressed from *e* to *f*, and elevated from *g* to *h*. In both cases the wing describes a waved track, as shown at *e g*, *g i*, which clearly shows that the wing strikes *downwards and forwards* during the down stroke, and *upwards and forwards* during the up stroke. The wing, in fact, is always advancing, its under surface attacking the air like a boy's kite. If, on the other hand, the wing be forcibly depressed, as indicated by the heavy wave line *a c*, and left to itself, it will as surely rise again, and describe a waved track, as shown at *c e*. This it does in virtue of its flexibility and elasticity, aided by the recoil obtained from the air. In other words, it is not necessary to elevate the wing forcibly in the direction *c d* to obtain the upward and forward movement *c e*. One impulse communicated at *a* causes the wing to travel to *e*, and a second impulse communicated at *e* causes it to travel to *i*. It follows from this that a series of vigorous down impulses would, *if a certain interval were allowed to elapse between them*, beget a corresponding series of up impulses, in accordance with the law of action and reaction, the wing and the air under these circumstances

FIG. 10.

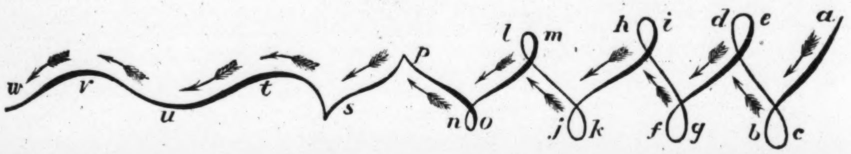
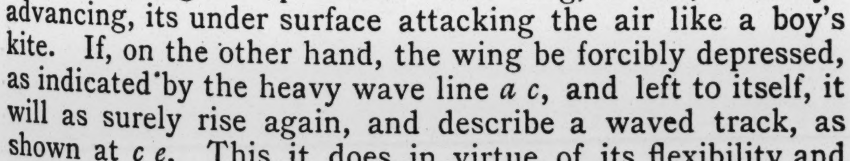


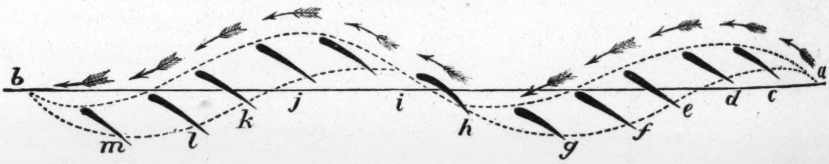
FIG. 11.



being alternately active and passive: I say if a certain interval were allowed to elapse between every two down strokes; but this is practically impossible, as the wing is driven with such energy that there is positively no time to waste in waiting for the purely mechanical ascent of the wing. That the ascent of the pinion is not, and ought not to be, entirely due to the reaction of the air, is proved by the fact that in flying creatures (certainly in the bat and bird) there are distinct elevator muscles and elastic ligaments, delegated to the performance of this function. The reaction of the air is therefore only one of the forces employed in elevating the wing; the others are vito-mechanical in their nature."

"*The Body and Wings move in Opposite Curves.*—I have stated that the wing advances in a waved line, as shown at *a c e g i* of Fig. 11; and the same remark holds true, within certain limits, of the body, as indicated at 1, 2, 3, 4, and 5 of the same figure. Thus, when the wing descends in the curve *a e*, it elevates the body in a corresponding but minor curve, as shown at 1, 2; when, on the other hand, the wing ascends in the curve *c e*, the body falls or descends in a corresponding but smaller curve (2, 3), and so on *ad infinitum*. The undulations made by the body are so trifling when compared with those made by the wing that they are apt to be overlooked. They are, however, deserving of attention, as they exercise an important influence on the undulations made by the wing, the body and wing swinging forward in space alternately, the one rising when the other is falling, and *vice versa*. Flight may be regarded as the resultant of three forces:—the *muscular and elastic force*, residing in the wing, which causes the pinion to act as a true kite, both during the down and up strokes; the *weight of the body*, which becomes a force the instant the trunk is lifted from the ground, from its tendency to fall downwards and forwards; and *the recoil obtained from the air* by the rapid action of the wing. These three forces may be said to be active and passive by turns."

FIG. 12.



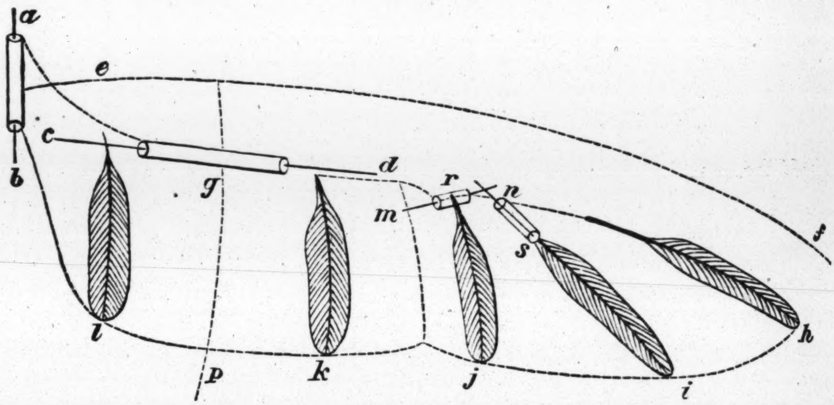
"*The Wing acts as a true Kite both during the Down and Up Strokes.*—If, as I have endeavoured to explain, the wing, even when elevated and depressed in a strictly vertical direction, inevitably and invariably darts forward (Fig. 11), it follows as a consequence that the wing, as already partly explained, flies forwards as a true kite, both during the down and up strokes, as shown at *c d e f g h i j k l m* of Fig. 12, and that its under concave or biting surface, in virtue of the forward travel communicated to it by the body in motion, is closely applied to the air, both during its ascent and descent, a fact hitherto overlooked, but one of considerable importance, as showing how the wing furnishes a persistent buoyancy, alike when it rises and falls."

"*Where the Kite Formed by the Wing Differs from the Boy's Kite.*—The natural kite formed by the wing differs from the artificial kite only in this, that the former is movable in all its parts, and more or less flexible and elastic, the latter being comparatively rigid. The flexibility and elasticity of the kite formed by the natural wing is rendered necessary by the fact that the wing is articulated or hinged at its root; its different parts travelling at various degrees of speed in proportion as they are removed from the axis of rotation. Thus the tip of the wing travels through a much greater space in a given time than a portion nearer the root. If the wing was not flexible and elastic, it would be impossible to reverse it at the end of the up and down strokes, so as to produce a continuous vibration. The wing is also practically hinged along its anterior margin, so that the posterior margin of the wing travels through a much greater space in a given time than a portion nearer the anterior margin. The compound rotation of the wing is greatly facilitated by the flexible and elastic properties of the pinion."

"*Compound Rotation of the Wing.*—The wing during its vibration rotates upon two separate centres, the tip rotating upon the root of the wing as an axis (short axis of wing), the posterior margin rotating upon the anterior margin (long axis of wing). *Vide a b* and *c d* of Fig. 13. This compound rotation goes on throughout the entire down and up strokes, and is intimately associated with the power which the wing possesses of alternately seizing and evading the air. It is this arrangement which enables the wing to present an infinity of inclined surfaces to the air—the angle of inclination being increased or diminished at any stage of the down and up stroke."

"*The Wing of the Bird Cranked slightly Forwards—the Compound Rotation of the Rowing Feathers.*—It will be observed from Fig. 13 that the wing is cranked somewhat forwards (compare position of axis *a b* with that of axis *c d*), a very slight movement of rotation at *c d* being accompanied by a considerable rotation of the posterior margin (*h i j k l*). This figure also shows that the individual primary, secondary, and tertiary feathers of the bird's wing have each what is equivalent to a long and a short axis. Thus the primary and secondary feathers marked *h i j k l* are capable of rotating on their long axes (*r s*) and upon their short axes (*m n*). The feathers rotate upon their long axes in a direction from below upwards during the down stroke, to make the wing impervious to air; and from above downwards during the up stroke, to enable the air to pass through. The primary, secondary, and tertiary feathers have thus a distinctly valvular action. They rotate upon their short axes (*m n*) during the descent and ascent of the wing, the tip of the feathers rising slightly during the descent of the pinion and falling during its ascent."

FIG. 13.



"*The Wing during its Vibration produces a Cross Pulsation.*—The oscillation of the wing on two separate axes—the one running parallel with the body of the bird, the other at right angles to it—is well worthy of attention, as showing that the wing attacks the air on which it operates in every direction, and at almost the same moment, viz., from within outwards, and from above downwards, during the down or effective stroke; and from without inwards, and from below upwards, during the up or return stroke. As a corollary to the foregoing, the wing may be said to agitate the air in two principal directions, viz., from within outwards, or the reverse, and from behind forwards, or the reverse, the agitation in question producing two powerful pulsations—a longitudinal and a lateral; the longitudinal running in the direction of the *length* of the wing, the lateral in the direction of its *breadth*. As, however, the curves of the wing glide into each other when the wing is in motion, so the one pulsation merges into the other by a series of intermediate and lesser pulsations.

The longitudinal and lateral pulsations occasioned by the wing in action may be fitly represented by waved tracks running at right angles to each other, the longitudinal waved track being the more distinct."

"*Analogy between the Wing in Motion and the Sounding of Sonorous Bodies.* — It is a remarkable circumstance that the undulation or wave made by the wing when the insect and bird are fixed or hovering before an object, and when they are progressing, corresponds in a marked manner with the track described by the stationary and progressive waves in fluids,* and likewise with the waves of sound.† This coincidence would seem to argue an intimate relation between the instrument and the medium on which it is destined to operate—the wing acting in those very curves into which the atmosphere is naturally thrown in the transmission of sound, in order, as appears to me, to secure the maximum of progression with the minimum of slip. Can it be that the animate and inanimate world reciprocate, and that animal bodies are made to impress the inanimate in precisely the same manner as the inanimate impress each other? This much seems certain :—The wind communicates to the water similar impulses to those communicated to it by the fish in swimming; and the wing in its vibrations impinges upon the air as an ordinary sound would. The extremities of quadrupeds, moreover, describe spiral tracks on the land when walking and running; so that one great law would seem to determine the course of the insect in the air, the fish in the water, and the quadruped on the land."

"*Weight contributes to Horizontal Flight.*—That the weight of the body plays an important part in the production of flight may be proved by a very simple experiment. If two primary feathers are fixed into an ordinary cork, and the apparatus is allowed to drop from a height, the cork does not fall vertically downwards, but *downwards* and *forwards*, and for the following reasons. The feathers are twisted flexible inclined planes, which arch in an upward direction. They are, in fact, true wings in the sense that an insect wing in one piece is a true wing. When dragged downwards by the cork, which would, if left to itself, fall vertically, they have what is virtually a down stroke added to them. Under these circumstances they inevitably dart forward, a struggle ensuing between the cork tending to fall vertically and the feathers tending to travel in a horizontal direction. As a consequence, the apparatus describes a curve before reaching the earth. This is due to the action and reaction of the feathers and air upon each other, and to the influence which gravity exerts upon the cork. The forward travel of the cork and feathers, as compared with the space through which they fall, is very great. Thus, in some instances, they advanced as much as a yard and a half in a descent of three yards. If the body of the sea gull depicted in Fig. 14 be taken to represent the cork, and the flexible mobile helices formed by the wings of the bird the primary or quill feathers, the conditions of the above experiment are reproduced with the utmost exactitude. A bird cannot be said to be flying until the trunk is swinging forward in space and taking part in the movement.

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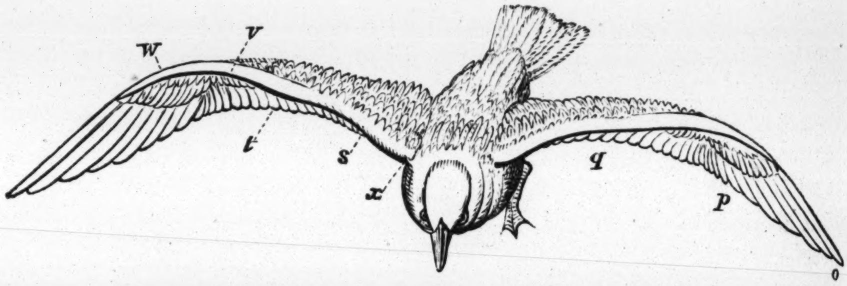
* Handbook of Natural Philosophy. Vol. on Electricity, Magnetism, and Acoustics, pp. 366-7. By Dr. LARDNER. London, 1863.

† *Op. cit.*, pp. 378, 379, 380.

FIG. 14.



Sea Gull suspending its body from its wings as from a parachute, and converting (by the aid of its wings) the vertical fall of the body into horizontal travel. This figure shows the twisted configuration of the wing of the bird, and how the anterior (*x s t v w*) and posterior (*q p o*) margins are disposed in different planes and appear to cross each other.

When the gannet throws itself from a cliff the inertia of the trunk at once comes into play, and relieves the bird from those herculean exertions required to raise it from the water when it is once fairly settled thereon. A swallow dropping from the eaves of a house, or a bat from a tower, afford illustrations of the same principle. However flying creatures acquire momentum, whether by throwing themselves from elevations or by the vigorous flapping of their wings, there can be no doubt, that the weight of their bodies operating upon the inclined planes formed by the pinions, contribute largely to the production of flight. This circumstance alone can explain why the albatross is able to sail about for an hour or more at a time, without once flapping its wings. Once launched into space, its motionless outspread pinions, which act as true kites, cause it even in a calm to descend *not vertically*, but in a *downward and forward curve;* and if a breeze be blowing, the air plays on the under surface of the wings in such a manner as enables it to pursue a horizontal course, or to ascend, descend, or wheel in any direction whatever. Weight is therefore a principal factor in flight. By its aid a flying animal is actually enabled to rest on the wing. But for this arrangement, the protracted migratory journeys of birds would be impossible."

"*The Wing at all times thoroughly under control.*—The advantage which the wing derives from being movable in all its parts consists in this, that it can be intelligently wielded even to its extremity. This enables the insect, bat, and bird, to tread and rise upon the air as a master—to subjugate it in fact. The wing, no doubt, abstracts an upward and onward recoil from the air, but in doing this it exercises a selective and controlling power: it seizes one current, evades another, and creates a third; it feels and paws the air as a quadruped would feel and paw a treacherous yielding surface. It is not difficult to comprehend why this should be so. If the flying creature is living, endowed with volition, and capable of directing its own course, it is surely more reasonable to suppose that it transmits to its travelling surfaces the peculiar movements necessary to progression, than that those movements should be the result of impact from fortuitous currents which it has no means of regulating. That the bird requires to control the wing, and that the wing requires to be in a condition to obey the behests of the will of the bird, is pretty evident from the fact that most of our domestic fowls can fly for considerable distances when they are young and when their wings are flexible; whereas when they are old and the wings stiff, they either do not fly at all or only for short distances, and with great difficulty. This is particularly the case with tame swans. This remark also holds true of the steamer or race-horse duck (*Anas brachyptera*), the younger specimens of which only are volant. In the older birds the wings become too rigid and the bodies too heavy for flight. Who that has watched a sea-mew struggling bravely with the storm, could doubt for a moment that the wings and every individual feather of the wings are perfectly under control? The whole bird is an embodiment of animation and power. The intelligent active eye, the easy graceful oscillation of the head and neck, the folding or partial folding of one or both wings,—nay more, the slight tremor or quiver of the individual feathers of part of the wings so rapid that only an experienced eye can detect it,—all confirm the belief that the living wing has not only the power of directing, controlling, and utilising natural currents, but of creating and utilising artificial ones, which is not less important. But for this power, what would enable the bat and bird to rise and fly in a calm or steer their course in a gale? It is erroneous to suppose that anything is left to chance where living organisms are concerned, or that animals endowed with volition and travelling surfaces should be denied the privilege of controlling the movements of those surfaces quite independently of the medium on or in which they are destined to operate. What would we say of that quadruped or that fish which depended for the major portion of its movements on the ground it trod, or the water it navigated? I will never forget the gratification afforded me on one occasion at Carlow (Ireland) by the flight of a pair of magnificent swans. The birds flew towards and past me, and I had my attention directed to their presence by a peculiarly loud whistling noise made by their wings. They flew about fifteen yards from the ground, and as their pinions were urged not much faster than those of the heron,[*] I had abundant leisure for studying their movements. The sight was very imposing, and as novel as it was grand. I had never seen anything before, and certainly have seen nothing since, that could in any way convey a more adequate idea of the prowess and guiding power which a bird may exert. What particularly struck me was the perfect mastery which they seemed to possess over everything. They had their wings and bodies visibly under control, and the air was attacked in a manner and with an energy which left little doubt in my mind that it played quite a subordinate part in the great problem before me. The necks of the birds were stretched out, and their bodies to a great extent rigid. They advanced with a steady stately motion, and swept past with a vigour and force which greatly impressed, and to a certain extent overawed, me at the time.* Their flight was what one could imagine that of a flying machine constructed in accordance with natural laws would be."

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[*] I have frequently timed the beats of the wings of the common heron (*Ardea cinerea*) at Warren Point (Ireland). In March, 1869, I was placed under unusually favourable circumstances for obtaining reliable results. I timed one bird high up over a lake for fifty seconds, and found that in that period it made fifty down and fifty up strokes; *i.e.*, one down and one up stroke per second. I timed another one in a heronry belonging to Major Hall. It was snowing at the time (March, 1869), but the birds, notwithstanding the inclemency of the weather and the early time of the year, were actively engaged in hatching, and required to be driven from their nests on the top of the larch trees by knocking against the trunks thereof with large sticks. One unusually anxious mother refused to leave the immediate neighbourhood of the tree containing her tender charge, and circled round and round it right overhead. I timed this bird for ten seconds, and found that she made ten down and ten up strokes; *i.e.*, one down and one up stroke per second precisely as before. I have therefore no hesitation in affirming that the heron, in ordinary flight, makes exactly sixty down and sixty up strokes per minute. The heron, however, like all other birds when pursued or agitated, has the power of greatly augmenting the number of its beats.

So much for Natural Flight; and now for a few words on Artificial Flight.

"*How to Construct an Artificial Wing on the Insect Type.*—The following appear to me to be essential features in the construction of an artificial wing:—

The wing should be of a generally triangular shape.

It should taper from the root towards the tip, and from the anterior margin in the direction of the posterior margin.

It should be convex above and concave below, and slightly twisted upon itself.

It should be flexible and elastic throughout, and should twist and untwist during its vibration, to produce figure-of-8 curves along its margins and throughout its substance.

Such a wing is represented at Fig. 15, and as it is forced into undulations when it is made to vibrate, I propose to designate it the *wave wing*.

If the wing is in more than one piece, joints and springs require to be added to the body of the pinion.

In making a wing in one piece on the model of the insect wing, such as that shown at Fig. 15, I employ one or more tapering elastic reeds, which arch from above downwards (*a b*) for the anterior margin. To this I add tapering elastic reeds, which radiate towards the tip of the wing, and which also arch from above downwards (*g*, *h*, *i*). These are so arranged with reference to the anterior margin of the wing, that they confer *a certain amount of spirality* upon the wing as a whole. The anterior (*a b*) and posterior (*c d*) margins are disposed in different planes, and appear to cross each other. I then add the covering of the wing, which may consist of india-rubber, silk, tracing cloth, linen, or any similar substance.

The artificial wave wing just described is endowed with the very remarkable property that it will fly in any direction, demonstrating more or less clearly that flight is essentially a progressive movement, *i. e.*, a horizontal rather than a vertical movement. Thus, if the anterior or thick margin of the wing be directed upwards, and the angle which the under surface of the wing makes with the horizon be something like 45°, the wing will, when made to vibrate by the hand, fly with an undulating motion *in an upward direction*, like a pigeon to its dovecot. If the under surface of the wing makes no angle, or a very small angle, with the horizon, it will dart forward in a series of curves, in a *horizontal direction*, like a crow in rapid horizontal flight. If the angle made by the under surface of the wing be reversed, so that the thick margin of the wing be directed downwards, the wing will describe a waved track, and fly downwards, as a sparrow from a house-top or from a tree. In all those movements progression is a necessity. The movements are continuous gliding *forward movements*. There is no halt or pause between the strokes, and if the angle which the under surface of the wing makes with the horizon be properly regulated, the amount of steady tractile and buoying power developed is truly astonishing. This form of wing, which may be regarded as the realisation of the figure-of-8 or wave theory of flight, elevates and propels both during the down and up strokes, and its working is accompanied with almost no slip.

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* The above observation was made at Carlow-on-the-Barrow, in October, 1867, and the account of it is abstracted from my note-book.

FIG. 15.

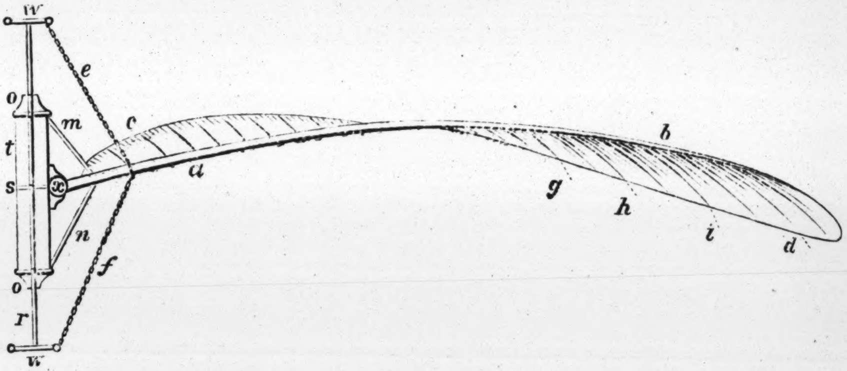

Fig. 15. Elastic spiral wing, which twists and untwists figure-of-8 fashion during its action to form a *mobile helix or screw*. This wing is vibrated by a direct piston action, and by a slight adjustment may be made to act vertically or horizontally, or at any degree of obliquity.

a, *b*, Anterior margin of wing, to which the neuræ or ribs are affixed. *c*, *d*, Posterior margin of wing crossing anterior one. *x*, Ball-and-socket joint at root of wing, the wing being attached to the side of the cylinder by the socket. *t*, Cylinder. *r*, Piston, with cross heads (*w w*) and piston head (*s*). *o*, *o*, Stuffing boxes. *e*, *f*, Driving chains. *m*, Superior elastic band, which assists in elevating the wing. *n*, Inferior elastic band, which antagonises *m*. The superior and inferior elastic bands assist in securing continuity of vibration, by removing the dead points at the end of the down and up strokes. To the superior and inferior elastic bands an anterior and posterior horizontal band is added. These run at right angles to the former and limit the action of the wing in an anterior and posterior direction.

It seems literally to float upon the air. No wing that is rigid in the anterior margin can twist and untwist during its action, and produce the figure-of-8 curves generated by the living wing. To produce the curves in question, the wing must be flexible, elastic, and capable of change of form in all its parts. The curves made by the artificial wave wing are largest when the vibration is slow, and least when the vibration is quick. In like manner, the air is thrown into large waves by the slow movement of a large wing, and into small waves by the rapid movement of a smaller wing. The size of the *wing curves* and *air waves* bear a fixed relation to each other, and both are dependent on the rapidity with which the wing is made to vibrate. This is proved by the fact that insects, in order to fly, require, as a rule, to drive their small wings with immense velocity. It is further proved by the fact that the small humming bird, in order to keep itself stationary before a flower, requires to oscillate its tiny wings with great rapidity, whereas the large humming bird (*Patagona gigas*), as was pointed out by Darwin, can attain the same object by flapping its large wings with a very slow and powerful movement. In the larger birds the movements are slowed in proportion to the size, and more especially in proportion to the length of the wing, the cranes and vultures moving the wings very leisurely, and the large oceanic birds dispensing in a great measure with the flapping of the wings, and trusting for progression and support to the wings in the expanded position. This leads me to conclude that very large wings may be driven with a comparatively slow motion, a matter of very considerable importance in artificial flight secured by the flapping of wings."

"*The Artificial Wave Wing can be driven at any speed—it can make its own currents, or utilise existing ones.*—One of the distinguishing features in the artificial wave wing is its adaptability. It can be driven slowly, or with astonishing rapidity. It has no dead points. It reverses instantly, and in such a manner as to dissipate neither time nor power. It alternately seizes and evades the air so as to extract a maximum amount of support with a minimum of slip, and a minimum expenditure of power. It supplies a degree of buoying and propelling power which is truly remarkable. Its buoying area is nearly equal to half a circle. It can act upon still air, and it can create and utilise its own currents. I proved this in the following manner:—I caused the wing to make a horizontal sweep from right to left over a candle; the wing rose steadily as a kite would, and after a brief interval, the flame of the candle was persistently blown from right to left. I then waited until the flame of the candle assumed its normal perpendicular position, after which I caused the wing to make another and opposite sweep from left to right. The wing again rose kite fashion, and the flame was a second time affected, being blown in this case from left to right. I now caused the wing to vibrate steadily and rapidly above the candle, with this curious result, that the flame did not incline alternately from right to left and from left to right; on the contrary, it was blown steadily away from me, *i.e.*, in the direction of the tip of the wing, thus showing that the artificial currents produced met and neutralised each other always at mid stroke. I also found that under these circumstances the buoying power of the wing was remarkably increased."

"*How the Wave Wing creates Currents, and rises upon them, and how the Air assists in elevating the Wing.*—In order to ascertain in what way the air contributes to the elevation of the wing, I made a series of experiments with natural and artificial wings. On concluding these experiments, I felt convinced that when the wing descends it compresses and pushes before it, in a downward and forward direction, a column of air corresponding to its area. The air rushes in from all sides to replace the displaced air, and so produces a circle of motion. The wing rises upon the outside of the circle referred to, so that it is not difficult to comprehend how the air comes indirectly to assist in elevating the wing. The artificial currents produced by the wing during its descent may be readily seen by partially filling a chamber with steam, smoke, or some impalpable white powder, and causing the wing to descend in its midst."

"*The Artificial Wave Wing as a Propeller.*—The wave wing makes an admirable propeller if its tip be directed *vertically downwards*, and the wing be lashed from side to side by a sculling figure-of-8 motion, similar to that executed by the tail of the fish. Three wave wings may be made to act in concert and with a very good result; two of them being made to vibrate in a more or less horizontal direction with a view to elevating, the third being turned in a downward direction, and acting at right angles to the others for the purpose of propelling."

"*A New Form of Aërial Screw.*—If two of the wave wings represented at Fig. 15 be placed end to end, and united to a vertical portion of tube to form a two-bladed screw, similar to that employed in navigation, a most powerful elastic aërial screw is at once produced, as seen at Fig. 16.

This screw, which for the sake of uniformity I denominate *the aërial wave screw*, possesses advantages for aërial purposes to which no form of *rigid screw* yet devised can lay claim. The way in which it clings to the air during its revolution and the degree of buoying power it possesses are quite astonishing. It is a self-ajusting, self-regulating screw, and as its component parts are flexible and elastic, it accommodates itself to the speed at which it is driven, and gives a uniform buoyancy. The slip I may add is nominal in amount. This screw is exceedingly light, and owes its efficiency to its shape and the graduated nature of its blades, the anterior margin of each blade being comparatively rigid, the posterior margin being comparatively flexible and more or less elastic. The blades are kites in the same sense that natural wings are kites, and are flown as such when the screw revolves. I find the aërial wave screw flies best and elevates most when its blades are inclined at a certain upward angle, as indicated in Fig. 16. The aërial wave screw may have the numbers of its blades increased by placing the one above the other, and two or more screws may be combined and made to revolve in opposite directions so as to make

FIG. 16.

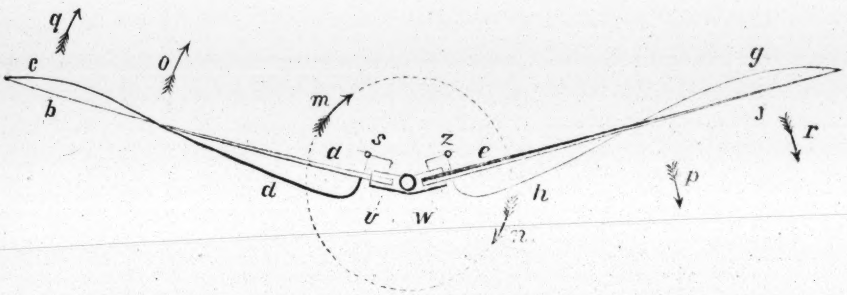

Fig. 16. Aërial wave screw whose blades are slightly twisted upon themselves (*a b*, *c d*; *e f*, *g h*), so that those portions nearest the root (*d h*) make a greater angle with the horizon than those parts nearer the tip (*b f*). The angle is thus adjusted to the speed attained by the different portions of the screw. The angle admits of further adjustment by means of the steel springs, *z*, *s*, these exercising a restraining, and to a certain extent a regulating, influence which effectually prevents shock.

It will be at once perceived from this figure that the portions of the screw marked *m* and *n* travel at a much lower speed than those portions marked *o* and *p*, and these again more slowly than those marked *q* and *r*. As, however, the angle which a wing or a portion of a wing, as I have pointed out, varies to accommodate itself to the speed attained by the wing, or a portion thereof, it follows, that to make the wave screw mechanically perfect, the angles made by its several portions must be accurately adapted to the travel of its several parts as indicated above.

x, Vertical tube for receiving driving shaft. *v*, *w*, Sockets in which the roots of the blades of the screw rotate, the degree of rotation being limited by steel springs, *z*, *s*. *a b*, *e f*, Tapering elastic reeds forming anterior or thick margins of blades of screw. *d c*, *h g*, Posterior or thin elastic margin of blades of screw. *m n*, *o p*, *q r*, Radii formed by the different portions of the blades of the screw when in operation. The arrows indicate the direction of travel.

them reciprocate, the one screw producing the current on which the other rises, as happens in natural wings."

"*The Aërial Wave Screw operates also upon Water.*—The form of screw just described is adapted in a marked manner for water, if the blades be made of carefully tempered finely graduated steel plates and reduced in size. It bears the same relation to, and produces the same results upon, water as the tail and fin of the fish. It throws its blades during its action into double figure-of-8 curves, similar in all respects to those produced on the anterior and posterior margins of the natural and artificial flying wing. As the speed attained by the several portions of each blade varies, so the angle at which each part of the blade strikes varies; the angles being always greatest towards the root of the blade, and least towards the tip. The angles made by the different portions of the blade are diminished in proportion as the speed with which the screw is driven is increased. The screw in this manner is self-adjusting, and extracts a large percentage of propelling power with very little force and surprisingly little slip. A similar result is obtained if two finely graduated angular-shaped steel plates be placed end to end (vertically or horizontally matters little), and applied to the water by a slight sculling figure-of-8 motion, analogous to that executed by the tail of the fish, porpoise, or whale. If the thick margins of the plates be directed forwards, and the thin ones backwards, an unusually effective propeller is produced. This form of propeller is likewise very effective in air."

IV. THE GEOLOGY OF THE STRAITS OF DOVER.*

By WILLIAM TOPLEY, F.G.S.,
Geological Survey of England and Wales.

ENGINEERS have for long busied themselves with discussions upon the feasibility of connecting England and France by railway, and during the last few years the question has come much before the general public. The late war for a time laid all such discussions on one side, but recently they have been revived, and once more have come prominently forward.

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* The authorities especially referred to in the preparation of this paper are as follows:—the Admiralty Charts; the Maps of the Geological Survey of England, Sheets 3 and 4; the Memoir on Sheet 4, by Mr. F. DREW; the Papers by Mr. PHILLIPS and Dr. FITTON, in the "Geological Transactions,"

The various schemes proposed are of three classes*:—a *Bridge* over the sea, a *Tube* on the bed of the sea, and a *Tunnel* beneath the bed of the sea. With the second of these, or the tube scheme, Geology has nothing to do. Concerning the first, there is the important question of foundation, upon which a geologist's opinion might be sought; but whether the answer were favourable or otherwise would but little affect the project. It is a question which can easily be settled by actual experiment, at comparatively little cost; and even if a good foundation were hard to find (an improbable supposition), engineers would be at no loss to make one: the question is solely one of expense.

With the third scheme, that of tunnelling, the case is very different. Here nearly all the questions which arise at the outset are such as can only be fully appreciated by one having some geological knowledge; they are, chiefly, the depth and thickness of the various rocks beneath the Channel, their extent, physical characters, permeability, &c. Perhaps in the present state of the question we shall be doing some service by (1) briefly narrating what is actually known of the geological structure of the coasts bordering the Straits of Dover; (2) by enquiring what help this knowledge affords us towards ascertaining the actual condition of the sea-bed; and (3) by testing the various tunnel schemes by the data thus obtained.

The physical geography and geological structure of the opposite coasts of the Channel have so many characters in common, that a description of one side will in great part serve for that of the other. There are, however, some points of difference which are of great importance in this question.

The most striking features of the Straits of Dover are the Chalk cliffs, rising steeply from the shore, of great height, and of dazzling whiteness. The similarity in the appearance of these cliffs led many old writers to speculate on their

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vol. v., 1st series and vol. iv., 2nd series; the Statement of the Executive Committee of the Channel Tunnel, with Engineer's Report and Diagram (1869). The thicknesses of the oolitic rocks in the Bas-Boulonnais are taken from a Paper by M. RIGAUX, in Bull. Soc. Acad. de Boulogne (1865); the geology of the Bas-Boulonnais is partly from a Map by M. DU SOUICH, and partly from original observations. A detailed account of the strata passed through in the Calais Well is given by Mr. MACKIE in the Geol. and Nat. Hist. Repertory, vol. i., p. 122: this is taken from a table and specimens preserved in the Museum at Calais.

* The proposal to construct large ferry-boats which will convey trains of carriages over the Channel does not concern us here.

former extension across the straits, uniting England and France. We shall presently see that the strata immediately underlying the Chalk present similar resemblances, a fact which the old writers overlooked.

Richard Verstegan was one of the oldest writers who gave any good and sound reasons for this opinion.[*] Others had suggested it before, but, says Verstegan, "These authors, following the opinion the one of the other, are rather content to think it sometimes so to have been, than to labour to finde out by sundry pregnant reasons that so it was indeed." "These cliffs on either side the sea, lying just opposite the one unto the other, both of one substance; that is of chalke, and flint, the sides of both towards the sea, plainly appearing to be broken off from some more of the same stuffe or matter, that it hath sometimes by nature been fastened unto, the length of the said cliffs along the sea shore being on the one side answerable in effect, to the length of the very like on the other side, and the distance between both, as some skilfull saylers report, not exceeding 24 English miles; are all great arguments to prove a conjunction in time long past, to have been between these two Countries; whereby men did pass on dry land from the one unto the other." Verstegan supposed that the separation has occurred since the Deluge, because all beasts were then destroyed but such as were taken into the ark. "But long after it could not be before the ravenous Woolf had made his kind nature known unto man, and therefore no man, unless he were mad, would ever transport of that race for the goodness of that breed, out of the continent into any Isles. . . . . But our Isle, as is aforesaid, continuing since the flood fastened by nature to the great continent these wicked beasts did of themselves pass over."

In following the chalk cliffs of England from Dover towards Folkestone, we find that near the latter place they terminate as sea-cliffs, but strike away inland in a fine cliff-like range of hills, which is known as the Chalk escarpment. The outline of this at Folkestone Hill is shown in Plate III., the height here is 575 feet. Standing on the edge of this escarpment and looking westward, we see the steep face sink rapidly down into the lower ground to the south; the beautifully rounded forms which chalk hills assume can nowhere be better studied than here. One of the most prominent points of the range is a projecting spur crowned by a fine camp; it is known as Cæsar's Camp, or Castle Hill.

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[*] Restitution of Decayed Intelligence, in Antiquities concerning the most noble and renowned English Nation, &c. This work was published in Antwerp in 1628. The quotations here given are from the edition of 1653, chap. 4.

Looking northward from the crest of the escarpment, we see that the land falls away with an almost imperceptible slope. This plateau is furrowed by long valleys, which, commencing near the escarpment, run northward into the larger valley of the Dour, which enters the sea at Dover. Beyond the valley of the Dour the ground rises in a second escarpment, the high land of which again falls away northward into the low-lying lands of Deal and Minster.

Returning now to the sea-cliff at Dover, and examining the rock of which it is composed, we shall find that, although all of chalk, it is of various kinds of chalk. The hill on which Dover Castle stands, and all to the north of it, is "Chalk-with-flints," or "Upper Chalk."* The hard flints, generally white outside but black when fractured, lying in regular rows, each row gradually inclining to the north, and thus showing the *dip* of the beds. Passing again towards Folkestone, we find, soon after leaving Dover, that the chalk of the lower part of the cliff loses its flints, whilst they still continue on above, but get higher and higher above the sea-level, until at Folkestone Hill they only cap the cliff and escarpment. The lower division of the chalk is known as the "Chalk-without-flints," or "Lower Chalk." Most of it resembles the Upper Chalk, save that flints are absent; but the lower part of it is different in character. This is less pure in composition, contains some clayey matter, and is darker in colour than the overlying beds. This is the "Grey chalk," or "Chalk marl," the latter name being perhaps more properly employed for only the lowest part. The Grey Chalk rises from the shore a little east of Lydden Spout, and forms the base of the cliff, until we reach the undercliff, where it is in great part hidden by masses of fallen rock. It reappears at the base of Folkestone Hill, and can be traced from thence all along the lower slope of the escarpment. It is through this Grey Chalk that one proposed tunnel is intended to be driven.

Emerging from beneath the Chalk, we find a thin band of green clayey sand (Upper Greensand). On the shore below the undercliff it is 20 feet or more in thickness, but inland it thins away, until, at the foot of Castle Hill, it is only 18 inches thick; still further east it apparently disappears altogether for many miles. It is an important formation in

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* The chalk of the Isle of Thanet is higher in the series than this. See a Paper by Mr. WHITAKER, Quart. Journ. Geol. Soc., vol. xxi., p. 395; and DOWKER, Geol. Mag., vol. vii., p. 466.

Surrey, Hants, and Sussex, containing there some hard beds of "firestone" and "Malm rock," which form a small escarpment. Compared with the overlying Grey Chalk the Upper Greensand is a permeable bed, or one through which water passes with tolerable freedom.

At the base of the chalk slope is a broad tract of clay, known as the Gault. This may be distinguished all round the country, at the foot of the Chalk escarpment, by most of it being in pasture. In Kent, Surrey, and Sussex, it averages about 100 feet in thickness. This bed is very constant in character; it is a stiff bluish and blackish clay, wholly impervious to water, and makes a strong dividing line between the partially porous beds above and the alternations of highly porous and partially impervious beds below.

The series of beds underlying the Gault is known as the Lower Greensand: the characters which they present are important, because it has been proposed that a submarine tunnel shall start from the English coast near Folkestone, in which case the tunnel would first be driven through these beds.

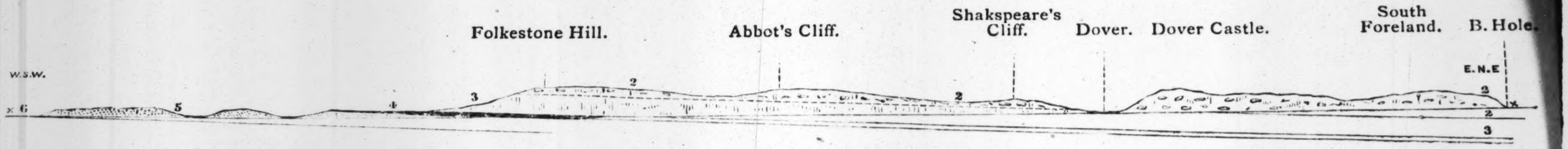
The Lower Greensand in Kent presents four well-marked divisions. Underlying the Gault is a bed of sand, known as the Folkestone Beds. It makes a very light soil, and is thus strikingly distinguished from the neighbouring Gault. It is highly porous, water passing through it with great rapidity. The division next below (Sandgate Beds) consists of clay and sandy clay; compared with the Folkestone Beds above, it is impervious to water, but it is much less so than the Gault. Its outcrop is frequently marked by a line of springs, and the water of wells sunk through the Folkestone Beds is held up by this stratum.

The third division of the Lower Greensand is known as the Hythe Beds: it consists of alternate beds of limestone and calcareous sand, the former being locally known as "Kentish Rag," and the latter as "Hassock." This division, like the Folkestone Beds, is highly porous. Below this is a band of clay, known as the Atherfield Clay, which geologists class with the Lower Greensand, because the fossils which it contains are, like those of that formation, of marine origin: for our present purpose it might be classed with the great mass of Weald Clay which underlies it, the fossils of which are of fresh-water origin.

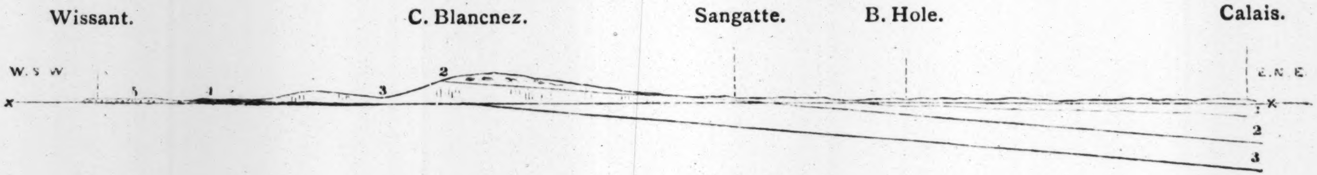
The Wealden Beds extend along the inland border of Romney Marsh, and form the high cliffs of eastern Sussex. They consist of alternations of clay and sand, the former largely predominating in the upper part, and the latter in

Plate III.

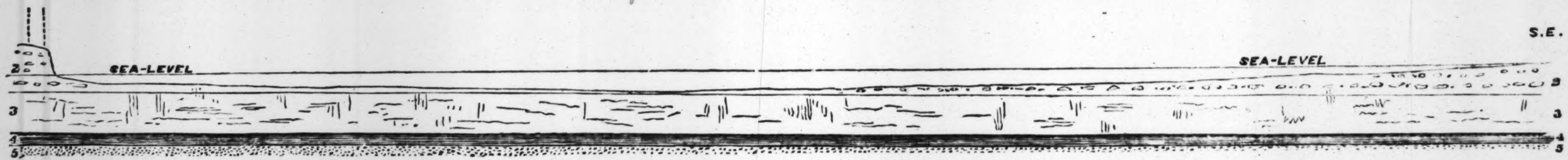
No. 1. SECTION ALONG THE ENGLISH COAST.



No. 2. SECTION ALONG THE FRENCH COAST.



No 3. SECTION ACROSS THE STRAITS OF DOVER.



Scale for Nos. 1 and 2 { Horizontal. 0 1 2 3 4 Miles.
Vertical. 500 1000 feet.

Scale for No. 3 ...... { Horizontal. 0 1 2 3 4 5 6 Miles.
Vertical. 500 1000 feet.

1. Drift and Tertiary Beds.
2. Chalk-with-flints.
3. Chalk-without-flints.
4. Upper Greensand and Gault.
5. Lower Greensand.
6. Weald Clay.

** Sea Level.

the lower part. The Weald Clay, as the highest division of these beds is called, can hardly be more than 500 feet thick on the Kentish coast,—probably it is less than that; but here there is no evidence by which we can determine its exact thickness. As a whole it is a stiff impervious clay, but it contains some thin beds of sand and limestone, which yield water.

The more sandy division below is the Hastings Beds: here are thick beds of porous sand and sandstone, divided by the Wadhurst Clay, which closely resembles Weald Clay in character. The Ashburnham Beds form the base of the Hastings Beds. These, as exposed on the coast, differ from the overlying Wealden division chiefly in the larger quantities of coloured clay which they contain. As a whole, this division is impervious, but there are many bands of sandstone which hold water.

All the beds here described dip to the north-east, and successively disappear as we pass in that direction. A well sunk through any one of the strata described will certainly meet with that which has been described as underlying it; but it is by no means certain that a well sunk, say, through the Chalk, would necessarily pass through *the whole* of those described. The reason of this we will immediately see.

Passing now to the French coast, we will suppose ourselves at Calais. This town stands on a wide flat of Tertiary beds covered up by sand and gravel. These beds underlie the whole of the flat country which stretches in a south-easterly direction past Guines. To the south of this there is rising and undulating ground, formed by the Chalk, which ends, as in Kent, with a fine escarpment. The various divisions of the Chalk are well seen along the cliffs between Sangatte and Wissant; these resemble those seen on the English coast, differing only in thickness, the Chalk-with-flints being much thinner on the French side of the Channel than on the English side. The lower divisions of the Chalk are more nearly alike.

Cropping out from beneath the Chalk we find, at first, the same beds as on the English coast; there is a thin band of Upper Greensand, a thicker band of Gault clay, and below these the top sandy division of the Lower Greensand (Folkestone Beds). These beds, as seen near Wissant, very closely resemble those of the English coast, differing only in thickness, they being each much thinner on the French than on the English coast. Perhaps the Folkestone Beds are the only division of the Lower Greensand which is here represented, for below them come some mottled clays, with sand, ironstone, and pebbles, which represent the thick Wealden formation of the English coast. The thickness of these is uncertain, but probably it nowhere exceeds 100 feet. Below them come the Oolitic rocks, which are not exposed on the coast of Kent or Sussex. We need not minutely describe these rocks. Only the higher divisions (Portland and Kimeridge Beds) are seen along the coast, the lower divisions cropping out inland. On the north-east of Marquise there are still lower beds, of the Carboniferous, Devonian, and Silurian formations, which occupy only a few square miles of the surface, but are known to underlie the higher rocks, at no great depth, over a great extent of country.

The Chalk escarpment which is cut by the coast near Wissant passes in a curved line round the country, and meets the coast again near Neufchatel, on the south of Boulogne. In a similar manner, the Chalk escarpment which is cut by the English coast at Folkestone passes round the country to the west, and reaches the Channel again at Beachy Head. The large district thus enclosed by the Chalk escarpment, on the English side, is known as the Weald. The similar district enclosed by the Chalk escarpment on the French side of the Channel is known as the Bas-Boulonnais. Although these two districts are now separated by the English Channel and the Straits of Dover, geologically considered they are one and the same.

Such being the geological structure of the coasts, we have now to consider what is the probable structure of the bed of the Channel. Here, of course, we can only be guided by analogy. We are entitled to assume that beds which have a constant character wherever we can study them, will probably maintain that character throughout the short space which intervenes between the French and English coasts. The beds of Chalk, which resemble each other on both sides, will, without doubt, have the same character beneath the bed of the Channel. When the beds are thicker on the one side than on the other, as is the case with the Chalk-with-flints, the intervening area will be occupied by that formation having its proper general character, but gradually diminishing in thickness as we pass from England to France. So, again, with the Gault; as there is no place all round the Weald and the Bas-Boulonnais where this division is absent, we may be perfectly sure that it is present in its proper position in the bed of the Channel, but with diminishing thickness as we pass from England to France. So, also, with the Folkestone Beds, which in the south-east of

England is the most constant division of the Lower Greensand, and in the Bas-Boulonnais is probably the only division of that formation which is represented. The Folkestone Beds at Wissant differ only in thickness from those at Folkestone; and there is no reason to doubt that this division also passes right across the Channel.

But here our certainty ends. We have seen that the Wealden formation is of very great thickness on the English coast; it is there not less than 1000 feet thick, and is perhaps considerably more. In the Bas-Boulonnais the Wealden Beds are probably not more than 100 feet in thickness, and it is quite uncertain which part of our English series they represent. Somewhere in the bed of the Channel the well-marked division of the English Wealden Beds must disappear, and they must gradually put on the characters which we find them to possess in the Bas-Boulonnais; but where this change takes place, and whether it is gradual or comparatively sudden, we have no means whatever of knowing. In the map which accompanies this paper I have shown the Weald Clay and the Hastings Beds striking out from the English shore in the direction in which, for some few miles, they will probably range. On the French side of the Channel I have also shown the Wealden Beds ranging for a short distance parallel with the Folkestone Beds; but I have not ventured to prolong the line far into the Channel. And, notwithstanding the fact that in some maps and sections which have appeared on this subject the lines have been projected with apparent confidence, there is not the slightest evidence to show in what direction the outcrops run.

In mid-channel there are two shoals, known as the Varne and the Ridge. It is a matter of great importance to know of what rocks these are composed; they will probably, however, be Portland or Wealden. From some experiments undertaken by M. Thomé de Gamond it seems probable that they are the former. The Portland Beds form the cliffs at Cap Grisnez, and under them there are the Kimeridge Beds. These rocks dip to the north-east; and, supposing M. de Gamond's observations to be correct, somewhere between Cap Grisnez and the Varne the Kimeridge Clay would wholly disappear. Somewhere to the west of the Varne and nearer to the English coast the Portland Beds would also disappear, and would be overlain by the Wealden series. Probably the Hastings Beds would immediately overlie them, and above these the Weald Clay would come on; but where the outcrop may be, or what the thickness of the various beds, we do not know.*

A similar doubt hangs over the submarine range of the Lower Greensand divisions, other than the Folkestone Beds. We have seen that the clayey Sandgate Beds and the calcareous Hythe Beds are well developed, and have their normal characters, on the Kentish coast; whilst on the French coast they are wholly absent. Somewhere, then, in the bed of the Channel these also must disappear; but where this change takes place we cannot tell.

There are two principal schemes proposed for connecting England and France by a submarine tunnel. There is that with which the names of Low and Hawkshaw are associated, which is proposed to run from near the South Foreland to a point between Sangatte and Calais. This tunnel it is supposed will be made wholly through the Chalk. The other is that of M. Thomé de Gamond, which he proposes to take from Eastwear Bay, near Folkestone, to Cap Grisnez.† This would pass through a number of different beds; how many we cannot tell, for it crosses the lines along which the changes above indicated must somewhere occur. There is no doubt that it would pass through all the English divisions of the Lower Greensand, for these it would intersect very near the coast; and we cannot suppose that the change which these must undergo takes place suddenly. Farther out in the Channel it would probably go through Weald Clay, possibly it might touch the Hastings Beds, beyond this it might intersect the Portland, and, finally, it would cut through the Kimeridge. But as we have no certain knowledge, nor even probable conjecture, where the outcrops of these various divisions occur, we cannot tell where the tunnel would intersect them. The various beds intersected by this tunnel are of very different characters; some are highly porous, some are wholly impervious. They all crop up somewhere in the bed of the Channel, and the porous strata among them are no doubt fully charged with water. There are two tunnels on the South Eastern Railway which pass through the Lower Greensand. There is that on the main line to Dover at Saltwood, which is driven partly through the porous Folkestone Beds and partly through the underlying Sand-

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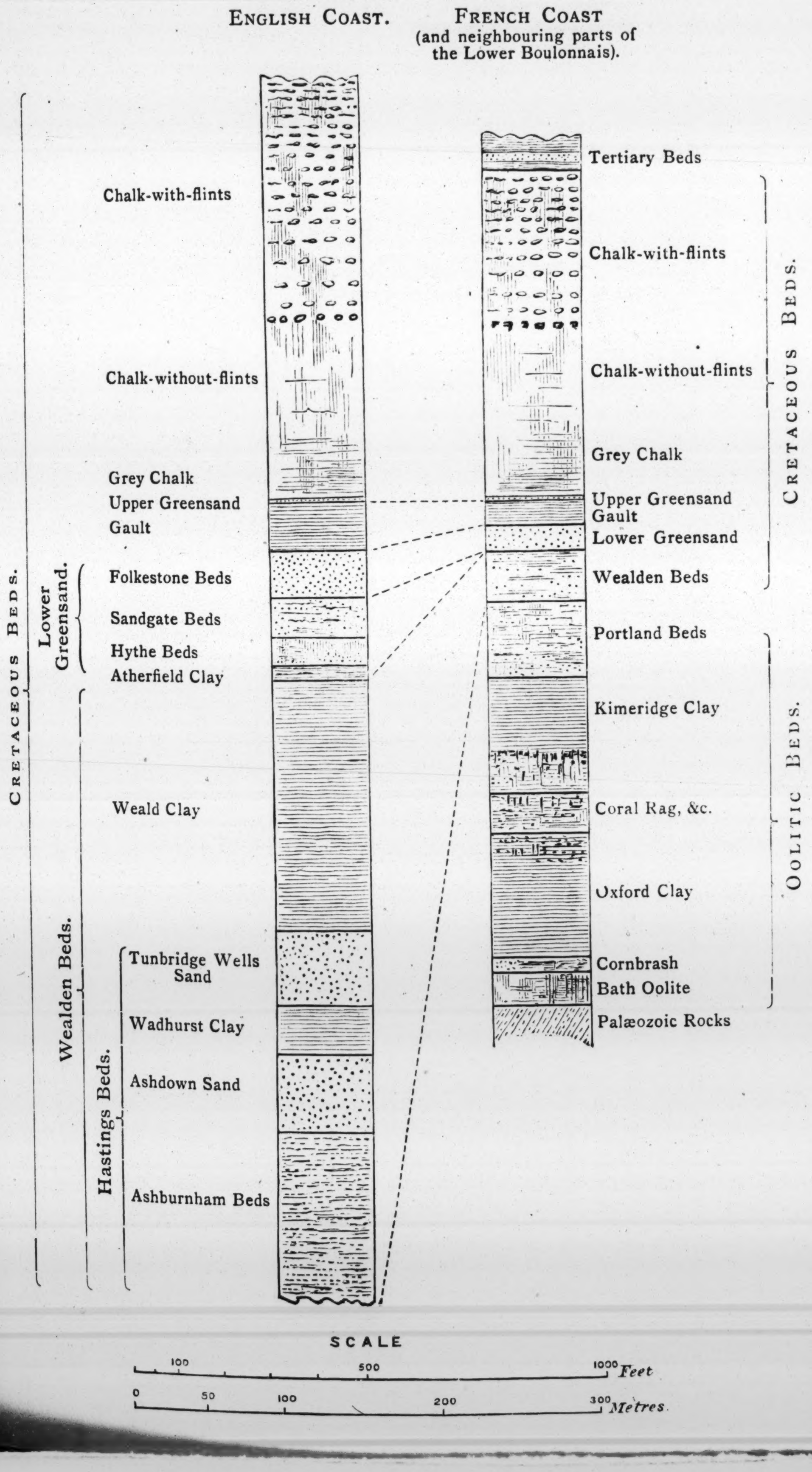
* M. Thomé de Gamond dived to the bottom between the Varne and the English shore, and brought up specimens of "Weald Clay;" but the exact spots at which they were obtained is not stated.

† M. de Gamond has apparently given in his adhesion to the schemes of Messrs. Low and Hawkshaw, so that there is really only one proposal now before the public.

Plate IV.

VERTICAL SECTIONS

ILLUSTRATING THE GEOLOGY OF THE STRAITS OF DOVER.



gate Beds. An account of the great difficulties which had to be surmounted here is given by Mr. Simms.* The Sevenoaks tunnel, on the new line to Tunbridge Wells, was driven through the Hythe Beds, and partly through the underlying Atherfield Clay. The former in their lower parts were largely charged with water, which pours out in a fully-formed stream from the tunnel's mouth.

The tunnel which it is proposed to take from the South Foreland to near Sangatte will, it is supposed, go entirely through the Chalk-without-flints.

The one great danger to be dreaded in driving a tunnel under the Channel is *water*, in quantities so great that it cannot be mastered. It is only in view of this danger that engineers need be much concerned with the geological structure of the Straits of Dover; for, supposing there were no great influx of water to be anticipated, it is a matter of *comparatively* little consequence whether the tunnel be driven through clay, sand, or chalk.

Water may occur chiefly from two causes:—the natural porosity of the rocks allowing water to pass freely down from the sea along the bedding into the tunnel; or faults and fissures cutting through the beds, and thus letting in water. We will consider the former first.

We have seen that two divisions of the Lower Greensand in East Kent are exceedingly porous (the Folkestone Beds and the Hythe Beds); these are *naturally* porous, and water passes freely along the bedding whether fissures be present or not. Any tunnel driven through them would, without much doubt, meet with very large quantities of water. Again, as regards the Wealden Beds; a large proportion of the Weald Clay is a stiff impervious clay, very well adapted for tunnelling where *clay only* occurs; but at various horizons within it we meet with beds of sand, which would most probably be charged with water. Still lower, and further out to sea, there would be the Hastings Beds, the sands of which are finer in grain, and perhaps less pervious to water than those of the Folkestone Beds, but still sufficiently so to make tunnelling through them a hazardous operation. The Portland Beds are mainly porous, whilst the Kimeridge Beds are mainly impervious; but in the latter series there are beds of sandstone which would probably yield much water.

If the tunnel could be driven wholly through the Gault there need not be much fear of water. But this cannot be done; the bed is too thin for this on the French coast. There is no other bed of clay which can be chosen, for no other goes right across the Channel. The Weald Clay of the English coast disappears, or else vastly changes its character before reaching the French coast. The Kimeridge Clay of the French coast may not pass beneath the English coast, and if it does so it would be at too great a depth to be of use. Moreover, these clays contain beds of sand, which if tapped by the tunnel would be, to say the least, exceedingly troublesome.

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* Practical Tunnelling as exemplified in the particulars of Bletchingley and Saltwood Tunnels. 1844. 2nd edition, 1859, by W. D. HASKELL.

The Chalk now remains to be considered. This, there is no reason to doubt, passes evenly beneath the Channel from shore to shore, and throughout it may be expected to maintain its usual characters, subject only to the decrease in thickness already noticed, The Chalk is well known to be a water-bearing bed; all the deep wells near London get their water from it. But in this respect it is not all alike.* The Upper Chalk is more pervious to water than the Lower Chalk, and in that the water does not pass at all readily through the *mass* of the chalk, but runs along joints and fissures, and especially along the lines of flint. In sinking wells through the Chalk it is frequently found that water is got at some of the bands of flint, whilst the intermediate bands of Chalk are either without such water, or else allow it to pass much more slowly.

In the drainage works at Norwich it was found that water percolates slowly through the re-arranged chalk which occurs there, but "in the hard and undisturbed chalk the water sooner disappears, although in larger quantities, through the various joints and fissures, and along the horizontal beds of flint, until it reaches the level of saturation."

The following paragraph is of sufficient importance to be reprinted here: †—

"The most important point in the sewerage works, as bearing indirectly upon the excavation of the proposed Channel Tunnel, is the fact that the chief difficulties met with in engineering operations occurred beneath the river level. Here the chalk and marl (re-arranged chalk) are thoroughly saturated, and, at only 20 feet below the level of the water in the river, it was found necessary to close-timber the top and sides of the tunnel before the brickwork could be put in, on account of its giving way by the pressure of water. The springs under the head of only 20 feet also boiled up with great force. On the contrary, above the water level, driftways were driven hundreds of feet in length, and left for months together without any timber shoring being required. It requires little imagination to perceive how great will be the pressure of water, and how immense the difficulties arising from it in the proposed Channel Tunnel excavated beneath 20 or 30 fathoms of water, and through a bed of hard chalk, doubtless abounding in joints and fissures. It has been the low level, 20 feet beneath that of the river, which has created the chief engineering difficulty and expense attending the sewerage works at Norwich."

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* These and similar questions are fully discussed by Mr. PRESTWICH in his "Water-Bearing Strata of London," 1851; pp. 57 to 74, and 134 to 142.

† J. E. TAYLOR and A. W. MORANT: "The Water-Bearing Strata in the Neighbourhood of Norwich. "Geological Magazine," vol. vii., p. 121, 1870.

If the foregoing description of the works at Norwich may be taken as a fair example of what would occur beneath the Channel, of course it is idle to think of driving a tunnel more than 20 miles long through such rocks, the whole of the water met with having probably to be raised to the surface by pumping. But there is no reason to think that the Chalk beneath the Channel will resemble this; rather is there every reason to think that it will be very different from it.

In the first place we must remember that these Norwich works were in the Chalk-with-flints, wherein water is sometimes abundant along certain lines. They were carried on very little below the river, and consequently any small joints or fissures would serve to convey the river-water down; whereas with a larger mass of rock above the works the joints and fissures might die out, or give place to others along different lines, and thus the water-channels would not be continuous.

But there has been no proposal to carry a tunnel through the Chalk-with-flints. It is proposed to make it mainly, if not entirely, through the lower part of the Chalk-without-flints, which is not itself a truly permeable bed. Indeed, even if it were fully charged with water, as probably it would be, it would yield only a small quantity of that water from its own mass; almost the whole of the water met with in the tunnel would enter by joints and fissures.

Joints and fissures in rocks are not formed as *open cracks* in the rocks; they become so by the incessant passage of water along them. Wherever water is passing through a jointed or fissured rock, especially if that rock be calcareous, it is gradually enlarging the cracks, and is rendering the passage of water more easy. But if the rock be beneath the sea, although it may be fully charged with water, this water may not, and probably would not, pass through it; hence there would be no tendency for the joints to increase in width. They would probably be closed cracks, not always easily detected, even by a tunnel intersecting them. In a similar manner we would not expect to find openings or small caverns in the Chalk, such as well-sinkers sometimes meet with; for these also are caused by the incessant passage of water wearing away the chalk more along certain lines than others.

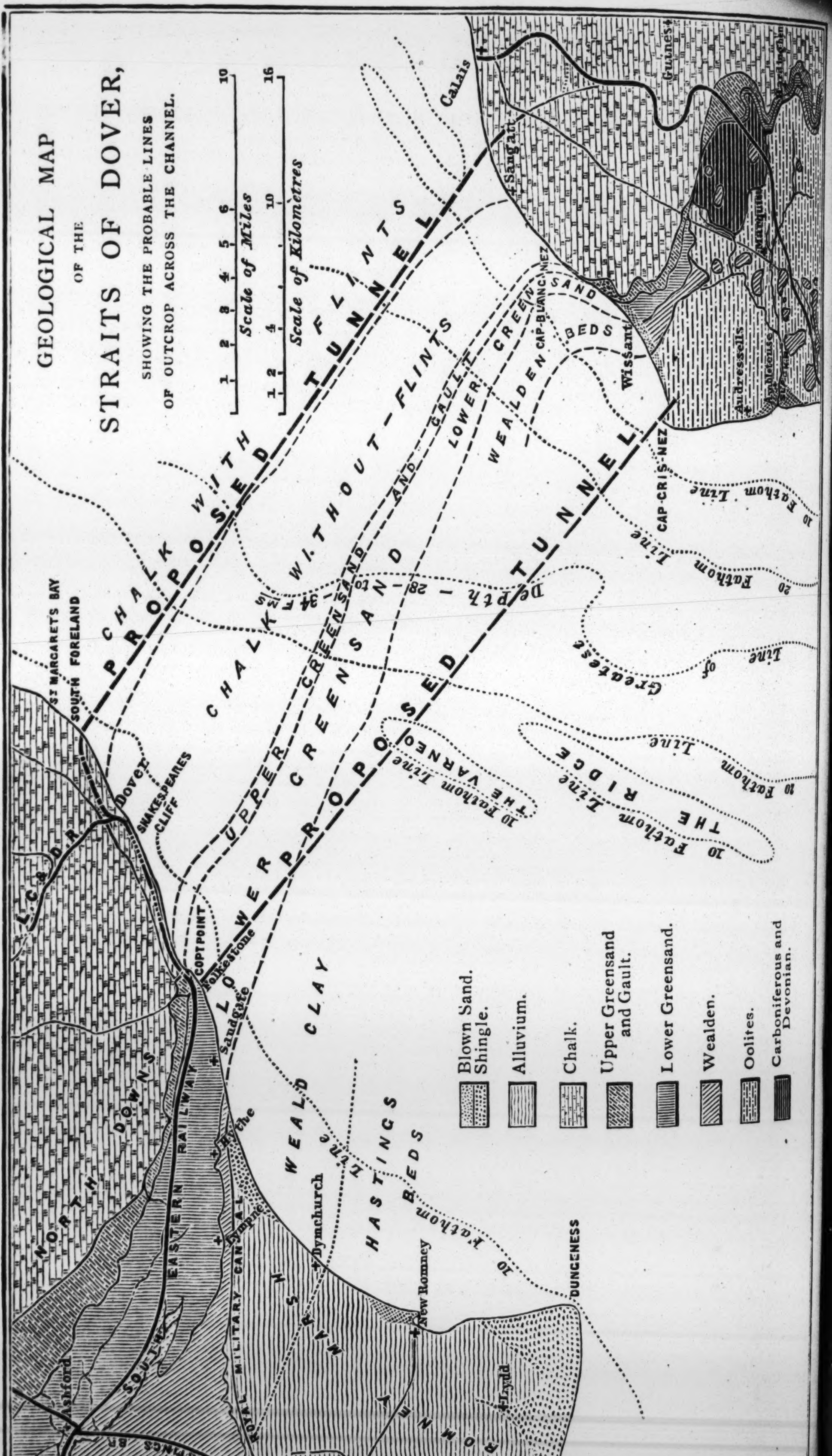
There is one other point connected with this subject which may be noticed here. It was said above that a deep well sunk through the Chalk would certainly meet with the bed next below it, but might not pass through the whole series of rocks if continued to a greater depth. The reason of this is, that under the north of France and the south-east of England there is a ridge of Palæozoic rocks, a part of which is exposed in the Bas-Boulonnais. It has been found in the deep well at Calais, and in wells at Harwich and Kentish Town. So far as is known the Chalk series is always perfect above it; some of the Gault is also found, but below that we may come directly on to the older rocks; or there may be a thickness, great or small, of the Lower Greensand and underlying beds.

As this ridge of old rocks is always, as far as is known, well below the Chalk, it is almost certain that a tunnel driven through the Chalk would not meet with it. But a tunnel driven through the underlying beds might do so. It is not at all likely that such would be the case, for on the French coast there is a good thickness of Oolitic strata above the old rocks. Apparently these old rocks are more deeply covered up by secondary strata as we pass westwards.

But if the Palæozoic rocks were met with in the tunnel it would probably not cause any inconvenience in the work. Perhaps it might turn out to be a very great advantage; for where these rocks have been reached in wells *no water has been obtained*. It may be that these rocks are destitute of water, certainly the water that they contain, if any, does not rise in the wells; and hence the wells and borings referred to have failed as sources of water-supply, although the information they give is of great interest and importance.

It is not likely that any tunnel crossing the Straits of Dover would meet with these old rocks; yet, as they are known to underlie the Chalk at no great depth, they may prove of great service; for if the shafts, which will be sunk on both coasts in starting the tunnel, were carried down well into the old rocks, the water might pass from the tunnel, down the shafts, into these old rocks, and there disappear.

Plate V.



GEOLOGICAL MAP
OF THE
STRAITS OF DOVER,
SHOWING THE PROBABLE LINES
OF OUTCROP ACROSS THE CHANNEL.

What is here suggested is often done on a small scale, where a dry mass of rock is known to underlie the surface. In quarries the water which collects in the bottom, being perhaps held up by an impervious bed of clay, immediately beneath the stone that is worked, is often got rid of by boring a hole down to a lower porous bed which contains no water. Of course this fact must first be ascertained, or the boring may bring up more water into the quarry. All well-sinkers are, however, familiar with the fact that water found in a well at one stratum is often lost if the well be continued further down; and therefore they often rest content with a comparatively small supply, rather than continue the well further down, and thus risk losing the whole.

Wet lands, overlying chalk or other limestones, are often drained by sinking a pit to such rocks, and conducting the surface drains into the pit. Town sewage has been disposed of in a similar manner, perhaps to be again pumped up by neighbouring deep wells.

Whether or not the Palæozoic rocks will carry off water in the way here suggested can easily be ascertained by experiment. If they fail to do so, then the water must be raised to the surface by pumping. If they do thus carry off water, there will not only be an immense saving in the cost of pumping, but, what is of far greater importance, there will be no danger of a great influx of water drowning out the tunnel.*

One great danger anticipated by some people in driving a tunnel beneath the Straits of Dover is, that of meeting with some great fault, or enormous dislocation of the strata, to which they suppose the formation of the Straits to be due. There is, however, not the slightest evidence to warrant any such anticipation. So far as we can judge from a study of the shores the chalk seems to pass evenly across the channel-bed, and such examinations of that bed as have been undertaken tend to confirm this opinion. The Straits of Dover have been worn through by the slow and long-continued action of the waves. It is, however, very likely that at one time, when the land stood at a higher level, and before the sea had eaten out the Straits, that a river ran from south to north through the chalk escarpment, which then stretched across from Folkestone to Wissant. The higher streams of this old river are the Rother on the

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* I do not wish much importance to be attached to these suggestions; for the rocks may be full of water and yet yield no rising water to wells; or they may be comparatively dry and yet so compact in structure as to prevent water from passing readily through them.

English side, the Wimereux and the Slack on the French side. Perhaps at that time, or at a still earlier period, the South Downs also stretched across the Channel, to join the chalk escarpment on the south of Boulogne. Between the North and South Downs there would be a mass of high land, ranging nearly east and west, joining the high cliffs of Fairlight with those of La Crèche.

The North Downs are now cut through by several rivers which drain the Weald; they are from east to west,—the Stour, the Medway, the Darent, the Mole, and the Wey. Whatever causes may have formed their valleys will also have formed the old valley in the Straits of Dover, which we may call that of the Rother. But there is no evidence to prove that any one of these valleys owes its formation to disruption of the strata; they have all been wholly excavated through the solid rocks by the rivers which run in them. We have, therefore, no reason to suppose that the Straits of Dover has been caused by faults or dislocations. On the contrary, we have every reason to suppose that the beds range uninterruptedly across from shore to shore.

There is probably no geological formation in England through which more tunnels or deep cuttings have been made than through the Chalk. All the railways, in approaching London, from the north, west, or south, must pass the Chalk escarpment; and although advantage has usually been taken of valleys which break through the escarpment, yet in many cases tunnels have been necessary. These tunnels and deep cuttings are generally driven through the lower beds of the Chalk,* the same as those through which it is proposed to take the Channel Tunnel. There are hundreds of wells in the London district which penetrate more or less deeply into the Chalk.

There is, therefore, abundance of information available as to the kind of work which must be undertaken. All these tunnels and cuttings are, however, driven above the sea-level, and similar works undertaken below the sea *may* meet with far greater difficulties. But this is not at all sure to be the case. The lower beds of chalk beneath the sea may contain no more water than those beneath the neighbouring shores.

There are numerous cases in the mining districts, both of metal and coal, in which the workings are carried far out below the bottom of the sea; yet it is only in exceptional cases that an extra quantity of water is met with in such workings; often, indeed, the workings are drier beneath the sea than beneath the land. Faults, too, are cut in the coal-workings beneath the sea, as beneath the land; but these give no more trouble and yield no more water in the one case than in the other. The same fault is frequently cut several times in parallel lines of workings.

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* Some of these were described in a Paper by Mr. S. HUGHES, "On Chalk Excavations, and on the Means adopted under Different Circumstances of Intersecting the Great Chalk Ridges of England, for the Purposes of Railway and Canal Communication." Civ. Eng. and Arch. Journ., vol. ii., p. 207, June, 1839.

To sum up the main geological points of this paper:—We have seen that the Chalk, the Gault, and the Folkestone Beds, have the same characters on both shores of the Channel, and that they may fairly be assumed to pass evenly across the bed of the Channel. The beds below the Folkestone Beds differ on opposite sides of the Channel, and we have no means of telling how these various beds run beneath the Channel, nor their probable thickness at different points.

Any tunnel driven through beds lower than the Folkestone Beds would therefore be undertaken with this disadvantage, that there would nowhere be any certainty as to the rocks which would have to be pierced. Of this, however, we may be quite sure,—that the water-bearing beds of these rocks would be fully charged with water, and that they are of such a nature that water would be discharged in large quantities into the tunnel.

A tunnel driven through the Chalk would have this advantage,—that it could certainly be taken through the Lower Chalk for most, if not all, the way; and though the Chalk itself may be fully charged with water, yet it would not readily discharge that water into the tunnel, except through fissures; and we have every reason to suppose that such fissures would be far less common and of far less importance than those met with in Chalk above the sea-level.

Lastly, there is no reason to suppose that any great fault will be met with during the progress of the work.

THE GOLD COINAGE.

THE right of coining in England, as in other countries, has always been the privilege of the Crown, and a national gold coinage begun with Henry III., but before that time gold pieces of money known as "byzants," of the value of about ten shillings, were coined at Constantinople and circulated freely in England. At a subsequent period "florences" were circulated in the same way, their name being derived from the fact that they had been struck at Florence. English gold coins have borne various names at different times. The "noble" of the reign of Edward III. was followed by the "angel" and "rose noble," or "rial," of Edward IV.; then came the "double rial," or "sovereign," of Henry VII., and the "laurel" of James I.; the latter coin was adopted by Charles II. at the Restoration, and afterwards became known as the "guinea." The present "sovereign" was issued by a proclamation, dated July 1st, 1817, under the authority of the latter part of section ii. of the Act of 56 of George III., cap. 68, passed in 1816. Its standard of fineness is 22 parts fine gold and 2 parts alloy; as it is impossible to obtain an exact admixture of metals in coining, a "margin" has at all times been allowed to Mint masters; this margin of departure from the standard for gold coins is at present fixed by law at 2 parts per 1000. There is also a "margin" permitted by law of departure from the standard weight, but modern improvements in machinery have permitted this departure to be confined within very narrow limits, although in former days it seems to have been used to some extent in defraying the expenses of coining. The present standard weight of a sovereign is 123·27447 grains, and the variation from the standard weight permitted by law is 1·6 in each 1000 parts.

Any person may take gold of not less than standard fineness to the Mint, and the Mint is bound to return for it the same weight in coin. The gold so "imported," as it is technically termed, must be accompanied by a "trade assay report," stating its degree of purity, and the importer or his agent must be present to verify, with the Mint officers, the weight of the importation. The bullion is then assayed at the Mint, and if the importer does not object to the degree of fineness thereby determined, it is melted with the proper proportion of alloy, and coined. The "alloy" is copper. Practically, however, the Bank of England is the only importer of gold bullion, because the owners of ingots can readily realise their value by selling them at the Bank, which is compelled by the Bank Charter Act of 1844 to purchase them at £3 17s. 9d. per oz. If they took the gold to the Mint they would get three-halfpence per ounce more for it, but then there would be the delay of melting and coining, and the disadvantage of receiving the money in sovereigns instead of bank-notes: the latter might be carried away in a purse, and the former might have to be carried away in a sack. The Bank of England accepts gold in ingots, weighing as a rule 200 ozs., from Rothschilds, Raphael and Sons, Browne and Wingrove, and other large houses, and they bear the "brands" of the said houses. The Bank of England makes a profit of about £2000 on each million by this three-halfpence per ounce.

As regards light gold coins, the law is that any person who is tendered such, "shall, by himself or others, cut, break, or otherwise deface, any such coin tendered to him in payment." Light gold is received by the Mint at the same rate as ingots. As only the Bank of England and a few other bodies comply with the requirements of the Act, it is to be feared there is much light gold in circulation, whereby the public will be the losers. Formerly coins were "sweated" by attrition or by being shaken together in large quantities in a bag; but comparatively recently the aid of electricity has been invoked, and precious metal is removed from coins by electro-dissolution. An interesting case of this kind was tried at the Central Criminal Court, January 31st, 1870.

The operations of the Mint may be divided into two classes—the metallurgical and the mechanical.

After the ingots reach the Mint from the Bank of England, the mechanical methods of turning them into sovereigns are very simple, although the machinery employed is necessarily made to do its work with the greatest precision and accuracy. The gold is first melted in a crucible about as big as a man's hat, then it is poured into moulds, whereby it is made into bars 24 inches long and half an inch deep. These bars are then rolled cold, by different sets of rollers, till they each form a band. These bands are then forcibly dragged between two motionless surfaces of steel to bring the band to a standard thickness, from which "blanks" for sovereigns can be punched. After the little blank discs are punched, they are passed through a machine which raises but does not mill their edges. In the next machine the sovereign is finished by stamping, and the one blow both impresses the effigies and dates and mills the edges. Next they are weighed by automatic machinery, which separates those which are of wrong weight from those which come within the limit of error permitted by law, and the former are sent back to the melting-pots to go all through the processes again. At various stages in these operations the gold has to be assayed by the Chemist of the Mint. The melting and rolling processes are of much the same character as making rails for railways, only the process with regard to gold is more delicate and exact; there are also special precautions to prevent loss of metal.

The ingots are assayed when they first reach the Mint, and then the amount of fine gold or of copper to be added to them, to bring them to the standard required by law, is calculated by a rule-of-three sum. Copper is used as the alloy. About 1200 ozs. of gold and alloy are sent to each melting-pot, and this operation is called "potting the ingots." It is advisable to consider the various processes in greater detail, and commencing with the operation of melting, it may be observed that there are seven furnaces at the Mint which are used for the fusion of the gold, each 1 foot square and 2 feet deep to the top of the bars. The melting-pot is made of a mixture of Stourbridge clay and plumbago; it is 9¼ inches deep and 7 inches in inside diameter at the top. The pot is placed in the furnace on a bottom which rests on two bars, then it is covered by its muffle and lid, and surrounded by fuel, which gradually heats the pots to redness; the ingots are then placed in it, and the alloy added through a funnel. When the whole mass is melted, the foreman stirs it with a rod made of plumbago and clay, and can tell by the feel when the metal reaches that particular state of viscosity which causes it, when moulded, to form a workable bar. The firing is then poked out, the muffle and lid of the pot removed, the pot lifted out with a tongs, and by suitable means supported by a loop of iron and a cord hanging from the ceiling. Before the melting, pieces of charcoal are placed in the bottom of the pot, for the purpose of reducing any oxide which may be present in the alloy, for copper will dissolve oxide of copper, and oxide of copper often makes the gold very brittle. This charcoal afterwards floats on the top of the melted gold, and a piece of stick held at the mouth of the pot whilst pouring into the moulds, stops the charcoal but not the gold. Each pot of gold forms seven bars. The moulds are made of cast-iron, and a large number, about twenty, of these moulds are mounted on a tram, which can be moved from one part of the building to another on rails. Each bar is marked to show from what pot it was poured; it is also marked with a letter which indicates the date of moulding. Bars for sovereigns are 2 feet long, 1·375 inches broad, ½ inch thick, and have an average weight of 180 ozs. Troy. Bars for half-sovereigns are 2 feet long, 1·125 inches broad, ½ inch thick, and weigh 170 ozs. Troy. Assay pieces are cut from each bar, and so labled as to show from which bar they come. The assay piece is flattened out, and from a bar a piece is cut, which is sent to the Assayer of the Mint.

The bars next have to be rolled. They are passed between steel rollers about seven times, the distance between the two rollers being reduced each time, and the mechanical arrangements are such that this rolling greatly lengthens the bar and reduces it to a band, but does not materially increase its breadth. Owing to the wear of the moulds in which the casting is done, the bars are never of exactly the same size. After the process of rolling, the resulting bands are very hard. Their ends are sheared off, and then they are 20 inches long.

The sheared bands, if for half-sovereigns, have next to be annealed. They are placed in copper tubes made without solder, and the ends of the tubes are luted on with clay. These tubes are then placed on an iron carriage, and run into the furnace, in which they are left for twenty minutes. Then the hot tubes are plunged into cold water as quickly as possible, with the bands inside. This rapid cooling prevents the oxidation of the copper; also, if they were cooled slowly, the gold would become so pasty and soft as to stick to the machinery. The bands are then rolled a little more, and passed through the last or "gauging" mill. Now and then the workman at this mill will punch a blank sovereign out of the fillet, and weigh it, to see that he is giving the fillets the right thickness, and he has the power of accurately adjusting small differences in distance between the rollers.

The fillets after being weighed are taken to the "drag" room, for they are not made of uniform thickness by simple rolling. The ends of the fillet are then passed to the extent of 2 inches through the rolls of a flatting mill. Then the fillet is passed to the draw-bench, where it is dragged between two pieces of steel, so as to become of the exact gauge. The flattened end is first put between the pieces of steel; an iron "dog" then bites hold of the end, and drags the rest of the fillet through the opening. The rolling mills and the dragging machinery are, of course, all driven by a steam-engine. After the fillets have passed the draw-bench, they are cut into lengths of 18 inches, and sent to the "trier," who punches out one or two blanks from each length, and weighs it or them very carefully, and he allows for a slight loss which will afterwards arise from annealing. The fillets are next taken into the cutting-out room, where the blanks for sovereigns are punched from them; the rest of the fillet then looks like a ribbon full of round holes, and these perforated bands or "scissel" are returned to the melting-pots.

The blanks are frequently examined, to see that their edges are smooth, and they are frequently weighed: this part of the operations is called "pounding." They are then put into bags in batches of about 720 ounces. Afterwards they are "rung" by boys, to sort out those which may be dumb or cracked. Cracked blanks are caused by bubbles of air enclosed in the metal at the time it is cast into bars. Next the blanks are taken to the edge-compressing machine, which rolls each blank with slight pressure, so as to give a "collar" to it. This machine rolls 700 blanks per minute. The blanks are afterwards annealed in copper tubes, 2804 being placed in each tube; the lids of the tubes are luted with clay, and then they are placed in a reverberatory furnace for about twenty minutes. They are then taken out, and when they are at a very low red heat, or at a temperature lower than that at which copper combines readily with oxygen, the tubes are plunged into a cistern of cold water. When the tubes are cold the blanks are removed, and after drying in sawdust they are ready for transmission to the coining-press.

The old atmospheric presses of Watt and Boulton are still in use at the Mint, and the obverse and reverse of the coin, as well as the milling of the edge, is completed at one operation. These old presses, which have done their work for so long a time, certainly are efficient, and there is no doubt that—looking to the nature of the coins produced by them—they leave but little to be desired; but a report of a Commission which visited the various Mints of Europe states that in all the European Mints visited, with the exception of Constantinople, the coining is performed by lever presses of German or French construction. The noise of the old atmospheric press is deafening, and doubtless the advantages and disadvantages of substituting the lever press for it will be duly weighed. And here we might venture to suggest that the designs on the coinage do at least admit of a somewhat more artistic treatment than that shown on the coins now in circulation. It should be remembered, however, that within the last two years Pistrucci's beautiful design of St. George and the Dragon has again been restored to the sovereign.

The last mechanical operation to which the finished coins are subjected is the weighing, which is performed by automatic balances devised by the late Mr. Cotton. It is impossible to describe these beautiful machines without the aid of diagrams; it will be sufficient to state that the coins are not only weighed, but are divided into three classes, the light, the heavy, and those which are either of standard weight or are within the "remedy" or allowance permitted by law.

Formerly the law directed that the "remedy" should be on a pound weight of the coins, but the Coinage Act of 1870 specified the actual legal weight of each individual coin, and rendered it necessary that each separate piece when issued, instead of each pound weight of pieces, should be within the limits of weight and fineness assigned to it: for instance, the weight of the sovereign is, as has been already stated, 123·2747 grs., and the variation permitted is 2-10ths of a grain above or below this weight.

It will be evident that in actual working a considerably smaller "remedy" must be used in order to render it impossible for a coin, the weight of which exceeds the prescribed limits, to pass into circulation. It will be evident to all who are familiar with the small dimensions of a weight which represents the 1-10th of a grain, that the attainment of accuracy in coinage must be attended with many difficulties. It is nevertheless the fact that the aggregate weight of the coins representing many millions in value does not exhibit a greater variation than 1 oz. from the exact standard.

It must be remembered that the law also directs coins to be produced of an alloy the true composition of which is rigorously guarded; therefore the most important chemical operations of the Mint is the process of assaying. A piece of metal is first brought to the exact weight by cutting or filing: each weighed portion is then added to molten admixtures of lead and silver contained in porous cups or "cupels" of phosphate of lime, which are arranged in rows in a muffle or small oven. The proportions of the latter metals are calculated so as to bear a definite relation to the supposed amount of gold and base metals present in the alloy. The lead oxidises and is absorbed by the porous "cupel," together with the copper and other oxidisable metals, and the silver and gold remain in the form of a button, which may also contain platinum, iridium, or metals possessing similar properties. The button is reduced by rolling to a thin strip, which is annealed and bent into a loose coil or "cornet." The cornet is placed in nitric acid of the specific gravity of 1·25, and the acid is maintained at incipient ebullition for fifteen minutes; the coil is then treated in a similar manner with nitric acid of the specific gravity of 1·4, the result being that the silver is removed by the action of the acid, and the gold remains in a spongy state. The sponge of the gold retains the original form of the coil, but it is necessary to impart a certain degree of coherence to the metal by annealing it at a dull red heat. A small quantity of silver is invariably retained with the gold. It is necessary therefore to make check assays on the pure gold, or on standards of known composition, upon which the accuracy of the result will in a great measure depend. The concluding process consists in weighing the gold cornet. The weights employed bear a decimal relation to the original weight of the assay piece operated upon, and the amount of gold therefore present in the alloy is at once indicated without further calculation.

Analysis of assay reports,* extracted from an official memorandum by the Chemist of the Mint, shows that coins taken from half a million of gold pieces, issued by the Mint in the year 1870, had the following composition:—

				Per Mille of Gold.
3	per cent	of the coins	contained	916·3
10	„	„	„	916·4
25	„	„	„	916·5
29	„	„	were of exact standard	916·6
14	„	„	contained	916·7
9	„	„	„	916·8
8	„	„	„	916·9
2	„	„	„	917·0
100				

Mean composition of the coins . { 916·617 gold.
83·383 copper.

1,000,000

That this result exhibits the attainment of a very high degree of accuracy will be evident when it is remembered that the allowance prescribed by law would have permitted a variation, above or below the exact standard, of two parts in the thousand.

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* Appendix to First Annual Report of the Deputy Master of the Mint (1870).

It is well to allude to a difficulty incidental to coining, arising from the occasional brittleness of the gold alloy, which is generally due to the presence of minute quantities of lead, antimony, arsenic, or bismuth. Occasionally the use of impure copper to alloy the gold introduced these other metals, so very great care is taken in the selection of pure samples of copper. Imperfect annealing will sometimes make the gold brittle. The brittleness, however, is more frequently due to the admixture of baser metals. There is a remedy, however, for the evil, which is found to be the most simple and efficacious. It consists in sending a stream of chlorine gas through the molten alloy; the gas rapidly acts upon the baser metals, combines with them, and the chlorides are then driven off as vapour. In order to test the process, an experiment was made on gold made brittle by the addition of 0·05 per cent antimony and 0·05 per cent of arsenic, making a total base alloy of 0·1 per cent, while 0·05 per cent of either metal would have produced very brittle gold. By passing a stream of chlorine through this gold, for 3½ to 4 minutes, it was converted into gold of excellent quality.

Formerly, when bars of gold were found to be unfit for coinage, the impure metal was returned by the Mint to the importer, and the original melters, who were held responsible, not unnaturally objected to bear the loss. Now, in consequence of the successful result of the above-mentioned experiments, the Mint no longer rejects bars which during the process of coining are proved to be brittle: thus all vexatious disputes have been avoided.

Of late years there have been many important changes in the establishment of the Mint: of these probably the most important was that effected in 1848, namely, the abolition of the contract system, by which for many centuries the Mint had been worked. The old "Masters of the Mint" were Contractors under the Crown, and their operations were controlled by officers, the principal of whom were the Warden and Controller, and the Assay Master, each exercising independent functions, the Assay Master being responsible to the Crown and to the people for the "standard fineness" of the coin.

After the abolition of the office of the "Moneyers," eminent scientific men have held the office of Master of the Mint. Now the office devolves upon the Chancellor of the Exchequer, and the appointment of an officer with the title Chemist of the Mint proves that the scientific requirements of the Department have been duly provided for; indeed, the Reports which lately have been presented to Parliament, while they abundantly show that the Department has undergone a thorough re-arrangement, also attest the fidelity and accuracy with which the operations of coining are conducted.

VI. BRIEF NOTES ON RECENT CHANGES IN BRITISH ARTILLERY MATÉRIEL.

By Capt. S. P. Oliver, F.R.G.S.

IN looking through the Extracts of the Quarterly Report of Proceedings of the Department of the Director-General of Ordnance (from vol. viii., part 1, to vol. ix., part 3), it will be observed that the labours of the various committees have not been light or unsuccessful. The results of various experiments and proposals are given by at least a dozen of these said committees, of whom the principal are the following, viz., committees on mitrailleurs, on torpedoes, on range-finders, on gunpowder and other explosives, on ship's deck and turret targets, on mountain artillery equipment, on rifled shell guns for field service and heavy rifled howitzers and mortars for vertical fire, on Palliser's method of strengthening cast-iron guns with internal tubes, on Palliser's projectiles, on traversing arrangements, on wads for preventing erosion of bore, on Moncrieff carriages, on shells and percussion fuzes for field service, on improvements of bronze, on proportions of ammunition for ordnance and small arms to be maintained in fortresses at home and abroad, besides Noble's important electro-ballistic experiments, and Majendie's experiments relative to the distance of cartridge-filling sheds, &c.

From an inspection of the reports of the above, it would appear that the following results are noticeable as affecting future warfare and modern requirements:—

I. The immediate introduction into the service of the small Gatling gun of 3 cwts., with musket-proof shields, and to be drawn by two horses. This gun is found to be a most effective weapon in defending villages, field intrenchments, caponnières, for covering the approach to bridges or *têtes-du-pont*, for defending a breach, and for employment in advanced trenches and field-works where economy of space is important. For naval purposes these machine guns are well adapted for use in the tops of vessels of war, for boat operations, service up close rivers, &c.

II. Gunpowder Service P.* (as the pebble-powder described in the last number of the "Quarterly Journal of Science" is officially designated) is to be introduced for battering charges of all rifled guns of 7-inch calibre and upwards, and for all service-charges of 40 lbs. and upwards, so soon as a sufficient quantity has been manufactured.

III. Additional experimental proof of the special value of compressed gun-cotton for demolition of stockades, bridges, &c., and for submarine mines. Capt. Noble also proposes to apply gun-cotton yarn as a fuze priming, it possessing the advantage of consuming almost instantaneously, thus not interfering with the burning of the fuse, whilst its sensitiveness makes ignition certain, even by the lowest charge.

IV. "Picric powder" is not unlikely to be used in future. It is an invention of the War Department chemist, Mr. Abel, who has been designing this explosive agent specially provided for charging shells. This mixture is neither so violent in its action as gun-cotton, nitroglycerine, or picrate of potash powder, but at the same time is a much more powerful explosive than gunpowder, and has other properties which appear to render it peculiarly adapted for employment in shells; it is readily and expeditiously prepared, can be pressed and granulated without difficulty, and at the same time is particularly remarkable for its *safety* as compared with all other explosive agents; it is, in fact, somewhat less sensitive to ignition by percussion than gunpowder. By recent experiments made it appears that picric powder, when used as a bursting charge for Palliser shells, will sustain the action of battering charges of R.L.G. powder in guns up to and including the 9-inch of 12 tons: the safety of this substance is being further tested from 10-inch and 12-inch guns.

V. The last explosive compound to be noticed, as likely to take no small part in future warfare, is Kreb's patent "lithofracteur," which is in use in the Prussian service. From Mr. Abel's analysis it appears to be composed as follows:—

Nitroglycerine	42	parts
Nitrate of soda	25	,,
Sulphur	4	,,
Sand, siliceous earth, sawdust, and coarsely-powdered coal	29	,,
	100	,,

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* See "Modern Cannon Powders," Quart. Journ. of Science for January, 1872, p. 58.

The "lithofracteur" differs from the nitroglycerine preparation called "*dynamite*" chiefly in containing a proportion of gunpowder constituents, viz., saltpetre, carbon, and sulphur, mixed up with the other ingredients. From the samples analysed it appears that this substance is crudely mixed, varies considerably in composition, and possesses no improvement over dynamite. On the 20th February, 1872, some exceedingly instructive trials of this compound were made—by Professor Engels, of M. Kreb's Cologne factory—at Mr. France's Breidden Quarry, on the banks of the Severn, near Shrewsbury, before the W. O. Committee, when it appears to have most favourably endured the various tests, both chemical (to ascertain the fuming and explosive points) and mechanical (to test its safety under heavy blows and concussion); for instance, 5 lbs. of lithofracteur was exposed to a fierce flame and consumed without explosion. Cartridges of it were subjected to heavy blows, such as the fall of round shot upon them, when the plastic substance, although squeezed out, neither inflamed nor exploded. Similarly, it was ignited by a Bickford fuse in confinement, and inflamed without explosion. Naked cartridges fixed to buffers of a railway truck, allowed to run on an incline into violent collision with a stationary one, also failed to explode. On the other hand, the same substance when fired with a Bickford fuze and detonator, in thin zinc tubes 4¼ inches in diameter, either against stockades, in mines, or under water, exploded with inconceivable violence, the explosion in each case being perfect. It was stated that M. Rietschoten has conceived the bold proposition of cutting through a sandbank of 1500 yards breadth, off Rotterdam, and so forming a deep channel through it by sinking tubing of that length charged with 10 tons of lithofracteur. For the defence of channels and entrances to our harbours nothing can be imagined more effective. The serious objection against it seems to be that, after keeping, the folds of thin paper of the cartridge become saturated with nitro-glycerine, absorbed from the material within, so that, according to Mr. Abel, in the application of it the hands of the operators must become soiled with that poisonous substance. No doubt this will be obviated.

VI. For the better prevention of the erosion in the bores of rifled guns, various descriptions of wads have been proposed and experimented upon. The Royal Laboratory paper wads appear to be objectionable on account of pieces of them flying back in a state of ignition, which has, in the case of the Bolton's wads, been already supposed to account for a dangerous accident on board H.M.S. *Minotaur,* when a 14-lb. cartridge exploded in the hands of No. 3 of a detachment, by which two men were severely burnt and eleven others scorched and singed. A coating of Szerelemy's zopissa cement applied to Bolton's wads has also been found impracticable, as it is found not to prevent them catching fire and burning to a very dangerous extent. Col. Reilly proposes a hempen wad with tin or copper edges, similar to that used in the Prussian breech-loading rifled guns, which has been found to effectually check the rush of gas over the seat of the projectile. Capt. Noble has experimented on several natures of wads, consisting either of tin cups with short deep or split flanges, or of cowhide cups with similar flanges, or a combination of cowhide and tin cup; the conclusion arrived at being against the tin cups, in consequence of their tendency to fly about in front of the guns, whilst the cowhide cups with deep flanges appeared to answer best as a gas check. Although Major Bolton has succeeded in making wads of an uninflammable material, it is found that the scoring of the bore is not entirely prevented, and at present the question of wads in any known form remains in an unsatisfactory state.

VII. Although the traversing arrangements for naval guns are such that heavy muzzle-loading rifled guns, at close intervals, are worked with ease and rapidity between decks, still hitherto on shore batteries—especially in casemates, where there is more room than on board ship—the old luff tackle traversing gear has been adhered to; and Sir Collingwood Dickson, the Inspector-General of Artillery, considers the present land traversing gear as utterly ineffective, the guns moving so slowly that it is impossible to obtain that rapidity of fire so absolutely necessary against ships moving under steam. Mr. Cunningham's ingenious training gear, fitted outside the rear racer, has been found to interfere with the convenient service of the gun; but a new system of coupling two fore or two hind trucks together, and driving by friction, the power being communicated by means of bevelled and toothed gear, is now recommended for general adoption: this plan possesses the great advantage of having the gear wholly contained in the platform; the matter is, however, of so much importance that the various details must be well considered before patterns are sealed.

VIII. The facilitation of loading heavy guns is also a question of importance, especially in bringing up the heavy shell and placing it in the bore; consequently various alterations have been made to shot-bearers and barrows, slings, muzzle-derricks, &c. With the same view it has been decided to ease off the loading side of the grooves at the muzzle, to facilitate the entry of the projectile into the bore. This is done by cutting away the lands, and thus widening the grooves to the extent of 1 inch, tapering down to the original width of the groove in a length of 2 inches, measured parallel to the axis of the bore, the corners being well rounded off.

IX. Amongst other changes, necessitated by the introduction of pebble powder, have been the regraduation and assimilation of Land-service and Sea-service tangent sights; and advantage has been taken of this opportunity to secure, as fully as the various classes of projectiles will allow, the introduction of an uniform system of applying the information which is engraved on the sight bars; and as the slow-motion elevating screw in tangent scales for land service is abolished in sights for guns of 64-pounder calibre and upwards, the land and sea service sights for guns of these natures will be interchangeable. Take the 7-inch M. L., for instance, the following information is to be found on the hexagonal bar of its centre hind sight:—On one side is given for double shell full range in yards, next common shell full fuze, common shell full yards, Palliser shot or shell and common shell battering yards, common shell battering fuze, and double shell full fuze.

The above are, of course, only a very few of the numerous alterations which are gradually changing the character of our Artillery *matériel;* but these few desultory notes, in which our heavy ordnance manufacture and trials between targets and shot and shell are necessarily excluded, will serve to show that our factories are not at a standstill. It is reported that Mr. Scott Russell has in hand a gun on an entirely new principle, with which he is going to astonish us.

NOTICES OF BOOKS.

The Debatable Land between This World and the Next. With Illustrative Narrations. By ROBERT DALE OWEN. London: Trübner and Co.

SIXTEEN years ago the author of this book, then American Minister at Naples, spent the evening of the 25th of March at the house of the Russian Minister, Mons. K—, in the company of several visitors from different parts of the world, among whom were the Chevalier de F— (the Tuscan Minister) and his lady. Madame K— introduced the subject of automatic writing; and declared her conviction that some persons had the power of thus replying correctly to questions, the true answers to which were entirely unknown to them. It was proposed to try the experiment; and each person present accordingly took pencil and paper, and waited the result. After a few minutes one lady's hand began to move, making irregular figures on the paper. Mr. Owen proposed that questions should be asked; whereupon Madame de F— said "Who gave me these pins?" pointing to three gold-headed pins that fastened her dress; adding "If Mrs. M— can answer that I shall believe." After a short time the lady's pencil slowly wrote out—(the last two words being written backwards)—"The one that gives you a Maid and a Cook. E." Madame de F— turned pale, and cried "Magic, if there be such a thing;" and then told the company that the pins had been given her by her cousin Elizabeth, who lived at Florence, and who at her request had sent her, a few days before, a lady's maid and a cook. Mr. Owen pondered over this strange occurrence, and determined to get to the bottom of it. Mrs. M— was not a Spiritualist. Madame de F— had only been a few weeks in Naples, had not mentioned even her cousin's name to any one, and had the slightest possible acquaintance with Mrs. M—, having only just exchanged cards with her. She expressed the strongest conviction that the three or four facts, accurately stated in the few words written, could not possibly have become known out of her own family. Mr. Owen was then a complete sceptic; but this circumstance induced a course of study which has been continued for fifteen years, and which eventually changed the whole feelings and tenour of his life. He is now a confirmed Spiritualist; that is, he not only believes the phenomena to be real, but he has satisfied himself that they furnish a sufficient proof of a future existence for man. Yet, it may surprise some of our readers to hear, he is fully imbued with the spirit and teachings of modern science; and his book is one continued protest against the miraculous. He maintains that all these phenomena happen under law, just as much as do the various phenomena (many of them still inexplicable by science) presented by plants, animals, or man. He treats this question seriously and dispassionately, as the great question of the age; which he may well do, since he claims that it furnishes an experimental proof of immortality. He writes with the earnestness suited to such a theme, and with the sense of responsibility of one who, by long and patient study, has arrived at important truths of the highest value to his fellow men. Rationalism, he tells us, cannot object to this belief, that it contravenes the doctrine of law; for its phenomena occur strictly under law: nor yet that it assumes the existence, in spiritual matters, of that direct agency of God which the naturalist finds nowhere in the physical universe; for its revealings come to man mediately only: nor yet that it is dogmatic, exclusive, or intolerant, as Infallibility is; for its adherents adduce experimental evidence, open to all men, and gleaned after the inductive method, for the faith that is in them. He shows us how important it was for the welfare of man that the belief in such phenomena should die out when it did, and leave us free to develope the doctrine of law, and to overthrow the very idea of infallible or absolute truth in matters of religion. All the horrors of witchcraft, and all the persecutions of priests, arose from the dogma of infallibility; for if that dogma had been true, persecution would not have been a crime, but a duty. The world could not reach the fundamental truths of these phenomena, or understand their real import, as long as they believed in the devil and in their own infallibility. Now, they are able to investigate the phenomena calmly, and reason upon them logically; and it is a suggestive fact that a large proportion of investigators are persons untrammelled by dogmatic creeds, and fully imbued with the teachings of modern science and philosophy. Mr. Owen thinks that the belief in modern spiritualism is spreading as fast as can be wished, and even faster than can be expected, considering that almost every educated man is prejudiced against the very attempt to investigate it. He well remarks, that the growth of any new-born hypothesis so startling in character, resembles that of a human being. During its infancy its suggestions carry small weight. It is listened to with a smile, and set aside with little ceremony. Throughout its years of nonage it may be said to have no rights of property, no privilege of appropriation. Proofs in its favour may present themselves from time to time, but they are not deemed entitled to a judgment, by the rules of evidence; they are listened to as fresh and amusing, but they have no legal virtue; they obtain no official record; they are not placed to the credit of the minor. An adolescent hypothesis is held to be outside the limits of human justice.

One of the best features of the book, as a literary work, is the distinctness with which each piece of evidence is presented, and the fulness and logical force with which its teachings are discussed. This is so different from what is usual when ghost stories are narrated (the authors appearing afraid to contemplate the logical consequences of a story they yet maintain to be true) that it will be well to give a few of the cases in outline, with the author's summing up at length, in order to see what a well-educated and highly-intelligent man can say in favour of what is generally considered to be an exploded superstition. Let us first take an old but well-authenticated story. Lord Erskine related to Lady Morgan (herself a perfect sceptic) the following personal narrative. On arriving at Edinburgh one morning, after a considerable absence from Scotland, he met, in the street, his father's old butler, looking very pale and wan. He asked him what brought him to Edinburgh. The butler replied, "To meet your honour, and solicit your interference with my Lord, to recover a sum due to me, which the steward at the last settlement did not pay." Lord Erskine then told the butler to step with him into a bookseller's shop close by, but on turning round again he was not to be seen. Puzzled at this he found out the man's wife, who lived in Edinburgh, when he learnt for the first time that the butler was dead, and that he had told his wife on his death-bed that the steward had wronged him of some money, and that when Master Tom returned he would see her righted. This Lord Erskine promised to do, and shortly afterwards kept his promise. Lady Morgan then says, "Either Lord Erskine did or did not believe this strange story: if he did, what a strange aberration of intellect! if he did not, what a stranger aberration from truth! My opinion is that he *did* believe it." Probably hundreds of readers of this narrative by Lady Morgan have said with her, "What a strange aberration of intellect!" and have thought no more about the matter. Mr. Owen is not satisfied with this careless mode of getting over a difficulty. His remarks are as follows: "What sort of mode to deal with alleged facts is this? A gentleman distinguished in a profession of which the eminent members are the best judges of evidence in the world—a gentleman whom the hearer believes to be truthful—relates what, on a certain day, and in a certain place, both specified, he saw and heard. What he saw was the appearance of one, in life well known to him, who had been some months dead. What he heard, from the same source, was a statement in regard to matters of which previously he had known nothing whatever; which statement, on after enquiry, he learns to be strictly true; a statement, too, which had occupied and interested the mind of the deceased just before his decease. The natural inference from these facts, if they are admitted, is that, under certain circumstances which as yet we may be unable to define, those over whom the death change has passed, still interested in the concerns of earth, may, for a time at least, retain the power of occasional interference in these concerns; for example, in an effort to right an injustice done. But rather than admit such an inference—rather than accept disinterested evidence coming from a witness acknowledged to be sincere, and known to the world as eminently capable—a lady of the world assumes to explain it away by summarily referring the whole to the 'dog-ears and folds of early impression!' What human testimony cannot be set aside on the same vague and idle assumption? It is time we should learn that the hypothesis of spiritual intervention is entitled to a fair trial, and that, in conducting that trial, we have no right to disregard the ordinary rules of evidence. Either Lord Erskine, one morning in Edinburgh, issuing from a bookseller's shop, met what wore the appearance of an old family servant who had been some months dead—or else Lord Erskine lied. Either Lord Erskine heard words spoken, as if that appearance had spoken them, which words contained a certain allegation touching business which that servant, dying, had left unsettled—or else Lord Erskine lied. Either Lord Erskine ascertained, by immediate personal interrogation of the widow, that her husband, on his death-bed, had made the self-same allegation to her which the apparition made to Lord Erskine—or else Lord Erskine lied. Finally, either, as the result of this appearance and its speech, a debt found due to the person whose counterpart it was, was actually paid to his widow—or else Lord Erskine lied. But Lady Morgan expresses her conviction that Lord Erskine did not lie."

"In itself, the thing was a trifle. Thousands on thousands of such cases of petty injustice occur, and pass away unnoticed and unredressed. To the widow it was, undoubtedly, of serious moment; but I think no sensible man will imagine it a matter to justify the direct interference of God. If so, and if Lord Erskine spoke truth, *an apparition is a natural phenomenon.*"

How is such evidence as this refuted or explained away? Scores, and even hundreds, of equally well attested facts are on record, but no attempt is ever made to explain them. They are simply ignored, and, in many cases admitted to be inexplicable. Yet this is not quite satisfactory, as any reader of Mr. Owen's book will be inclined to admit. "Punch" once made a Yankee debtor say—

> "This debt I have repudiated long ago;
> 'Tis therefore settled. Yet this Britisher
> Keeps for repayment worriting me still!"

So our philosophers declare that they have long ago decided these ghost stories to be all delusion; *therefore* they need only be ignored; and they feel much "worrited" that fresh evidence should be adduced and fresh converts made, some of whom are so unreasonable as to ask for a new trial on the ground that the former verdict was contrary to the evidence Let us, however, consider another case, the parties to which are intimately known to our author, and whose character is vouched for as above suspicion.

A young lady, Miss V., while at her aunt's country mansion, was, owing to press of visitors, asked to occupy a room believed to be haunted. Miss V. accepted it willingly, being quite fearless. Awaking in the night, she saw in her room a woman in old-fashioned dress, who, after a little while, came towards her, and seemed to try in vain to speak. Miss V. became frightened, drew the clothes over her face, and when she looked again the figure had disappeared. She then jumped up, and found the door of her room locked on the inside. With the light of day the impression somewhat faded; she began to think she must have imagined or dreamt it, and in a short time thought no more of the ghost. Some time afterwards Miss V. met with a friend interested in spiritualism, and had with her several *séances*. At one of them an alleged spirit announced herself as Sarah Clarke, a name unknown to both ladies. A communication was then received to the effect that she had many years ago been housekeeper in Miss V.'s family, and had vainly endeavoured to communicate with the young lady while she was staying in the old mansion; that her object was to confess a crime of which she had been guilty, and to ask her old mistress's pardon for it. She had stolen some family plate, and begged Miss V. to tell her aunt, and beg for her forgiveness. Next time Miss V. visited her aunt, she ascertained that Sarah Clarke *had* been housekeeper in the family thirty or forty years before,—that some plate *had* mysteriously disappeared, but that Sarah was much trusted, and was never suspected. The aunt declared that if Sarah Clarke had taken it she freely forgave her. From that time the haunted chamber was free from all disturbance. Mr. Owen comments on this, as follows: "Knowing the standing of the parties I am able to vouch for the truth of this story. Let us consider what it discloses as to the next world. There is repentance there as here. There is restless regret and sorrow for grave sin committed while here. There is anxious desire for pardon from those whom the spirit wronged during earth-life. In other words, the natural effects of evil doing follow us to our next phase of life; and, in that phase of life as in the present, we amend, and attain to better things by virtue of repentance. . . . . Another corollary is, that when such spiritual phenomena present themselves, an endeavour to establish communication with the manifesting spirit may result in benefit, alike to a denizen of the other world and a disturbed inhabitant of this. In this way Mrs. Propert (see p. 224), getting rid of the midnight foot-falls, might have been in quiet possession of her villa at this day. I invite attention also to the strong proof of identity furnished by Miss V.'s story. The name of the housekeeper was unknown to both ladies when her (alleged) spirit gave the message. There was nothing to suggest such a name or such a confession as was made. Yet on enquiry both name and confession were found to correspond with facts that had taken place thirty or forty years ago; to say nothing of a new fact, tallying with all the rest—the cessation of the spiritual visits, as soon as the visitor had no longer any motive to show herself."

"How extraordinary," many readers will exclaim, "that a man of Mr. Owen's ability should waste his time in discussing ghost stories!" It is indeed extraordinary; for do we not know all about possible and impossible spirits? Our men of science and our philosophers are not quite sure that a spirit is possible; but *if* possible, they are all quite clear that *spirits* would never behave in the ridiculously human way in which reputed ghosts invariably act. Let us, therefore, refuse to listen to these ghost stories told by people we know nothing of, and hear what Mr. Owen has to tell us of the wonders he has himself witnessed.

He spent an immense deal of time in trying to discover that gross imposture, the spirit rap, but in vain! For this purpose he once lived for a week in a medium's house, with full power to investigate. He walked all over the house with the medium, but the raps came everywhere. They sounded on the floor, walls, or ceiling of every room, on every article of furniture, on doors and windows, on the marble mantel-piece, and the steel grate. With the same medium they occurred on board a steamer, on the stool he sat on, on the keel of a small boat in the water, on the ground out of doors, on trees, and on rocks by the sea-shore. With every test that he could apply, he could find no physical cause for these sounds. Sometimes they occurred as delicate tickings, at others like blows of a sledge hammer—so tremendous that it seemed impossible any article of furniture could resist them: yet the table on which they resounded showed not a scratch! On almost all these occasions the rooms were searched, the doors were locked, and the mediums were held fast; yet Mr. Owen could never find out the trick! How strange, when the thing is said to be so simple that our men of science will not even take the trouble to refute it!

In the matter of table-moving he had no more success. When Faraday exposed table-turning, he remarked that experimenters who thought tables even rose in the air should suspend them in a balance, and see if the weight was affected by this supposed force. Mr. Owen, at the suggestion of the late Dr. Robert Chambers, did this. Together, they suspended a table, weighing exactly 121 lbs., about 8 inches from the floor, by a powerful steelyard: two mediums were present, whose feet and hands were attended to; yet, without any contact whatever, the table, when requested, became lighter, coming down to 60 lbs., having thus lost half its weight: when requested to be made heavier it weighed 144 lbs. What are we to make of this? Two thoroughly reliable witnesses and a balance tell us one thing; but men of science say it can't be true: which are we to trust?

Continuing his researches, Mr. Owen had sittings alone with a medium. He examined the room, he locked and *sealed* the doors, and took with him privately marked slips of paper. He held the medium's hands; yet writing was somehow effected on the paper placed under the table, both in pencil and ink. Yet more; on one occasion he saw part of the writing done, by a small luminous hand on the floor, holding the pencil. On this experiment Mr. Owen remarks as follows: "Were these spiritual autographs? What else? Had I not *seen* one of them written? Had I not seen one of these slips rise higher than the table, and sink back again? Had I not felt Kate's two hands under mine at the very time when that hand wrote and that paper rose and fell? Did Kate write eight or ten lines with both her hands clasped? Did I write them with my left hand without knowing it? Or had Kate brought the slips ready written? I picked them up, and examined them critically, one by one. My private mark on one corner of each—letters of the German alphabet, written in the German character—still there! What way out? Are the senses of seeing, hearing, and touch, in sane healthy persons, unworthy to be trusted? For me, common sense bars that way out. I see nothing unlikely—not to say incredible—in the theory that God may vouchsafe to man sensible proof of his immortality. For others, to whom spiritual intercourse seems an absurdity,—for those more especially to whom the hypothesis of another life wears the aspect of a baseless dream,—let them select their own path out of the difficulty. I think that, on any path they may take, they will have to accept theories infinitely less tenable than those they decide to reject."

Mr. Owen also saw much of Mr. Foster, the medium who has names written on his hands and arms. On one occasion Mr. Foster extended his hand upon the table; it was perfectly free from any mark whatever. Gradually a faint red mark appeared on the wrist, which increased till it formed the letter F, remained visible two or three minutes, and then faded away. This was the initial letter of a name Mr. Owen had secretly written on a piece of paper, and folded up tightly, and which was mixed with about twenty others on the table. Dr. Carpenter tells us (in a letter published in "The Spiritualist" of March 15, p. 21) that this is done by first tracing the writing on the tense skin with a hard point, and then rubbing the place to bring out the red blush. But unless we are to believe that Mr. Owen and the late Dr. Robert Chambers, as well as many other careful observers who have narrated their experiences with Mr. Foster, all make grossly false or imperfect statements, this explanation by no means covers the facts; as will be admitted by all who read Mr. Owen's narrative or the evidence of Mr. E. L. Blanchard given at page 135 of the "Report of the Committee of the Dialectical Society."

Having seen so many inexplicable things himself, Mr. Owen is quite ready to believe others, when they narrate their experiences; yet he often takes an immense deal of trouble to test and confirm them, as is well shown in the marvellous story of M. Bach and the old Spinet. To be properly understood this must be read in the full detail given by Mr. Owen: in outline it is as follows: Mons. Leon Bach purchased, at an old curiosity shop in Paris, a very ancient but beautiful *spinet*, as a present to his father, who is a great-grandson of *the* Bach, and is a composer and musical amateur. The next night the elder Bach dreamt that he saw a handsome young man, dressed in old court costume, and who told him that the spinet had been given to him by his master King Henry. He then said he would play on it an air, with words composed by the King, in memory of a lady he had greatly loved: he did so, and M. Bach woke in tears, touched by the pathos of the song. He went to sleep again; and on waking in the morning was amazed to find on his bed a sheet of paper, on which was written, in very old characters, both words and music of the song he had heard in his dream. It was said to be by Henry III., and the date inscribed on the spinet was a few years earlier. M. Bach, completely puzzled, showed the music to his friends, and among them were some spiritualists, from whom he heard, for the first time, their interpretation of the phenomena. Now comes the most wonderful part of the history. M. Bach became himself a writing medium; and through his hand was written, involuntarily, a statement that inside the spinet, in a secret niche near the key-board, was a parchment, nailed to the case, containing the lines written by King Henry when he gave the instrument to his musician. The four-line stanza, which it was said would be found on the parchment, was also given, and was followed by the signature—Baldazzarini. Father and son then set to work to search for this hidden scroll; and after two hours' close examination found, in a narrow slit, a piece of old parchment about eleven inches by three, containing, in very old writing, nearly the same words which M. Bach had written, and signed—Henry. This parchment was taken to the Bibliothèque Impériale, and submitted to experienced antiquarians, and was pronounced to be an undoubtedly genuine autograph of Henry III.

This is the story; but Mr. Owen is not content with ascertaining these facts at first hand, and obtaining photographs of the spinet and the parchment, of both of which he gives good representations. He also sets himself to hunt up historical confirmation of the story, and after much research and many failures, he finds that Baltasarini was an Italian musician, who came to France in 1577, and was in great favour with Henry III.; that the King was passionately attached to Marie de Cleves, who became wife of the Prince de Condé; and that several of the allusions to her in the verses corresponded to what was known of her history. Other minute details were also found to be historically accurate.

Mr. Owen then carefully discusses the nature of the evidence, the character of the persons concerned, and the possibility of deception. M. Bach is an old man of high character; and to suppose that he, suddenly and without conceivable motive, planned and carried out a most elaborate and complicated imposture, is to suppose what is wholly incredible; but Mr. Owen shows further, that the circumstances are such that M. Bach could not have been an impostor, even had he been so inclined, and concludes by remarking: "I do not think dispassionate readers will accept such violent improbabilities. But if not, what interesting suggestions touching spirit-intercourse and spirit-identity connect themselves with this simple narrative of M. Bach's spinet!"

Recurring to Mr. Owen's own experiences, perhaps the most astounding is his account of the gradual formation of an apparition, distinctly visible to several spectators. Every precaution was taken to render trick or imposture impossible; yet if so, what marvel of modern science is equal to this? What natural phenomenon so worthy of investigation! Our author's remarks on this case will sufficiently indicate its nature. He says: "My faith in the reality of this appearance is not at all shaken by reflecting that a Signor Blitz, or a Robert Houdin, having a theatre at command, arranged with ready entrances and exits, with practical trap-doors, with dark lanterns in the wings, with the means of producing dissolving views, could probably reproduce all I witnessed. But here were a few ladies, in private life and in moderate circumstances, quietly meeting in two apartments which were daily used as school-rooms by one of their number, containing not even a recess where a chair could be hidden away. They meet to satisfy a laudable curiosity, admitting visitors now and then by courtesy only. No remuneration is demanded, nor, very surely, would any have been accepted. They meet, on this occasion, at my request, after having discontinued their researches for months, vexed with unjust suspicions. They allow us to lock every exit, after a close examination of the rooms. Here is neither motive nor opportunity—to say nothing of qualification—for deception. The coin of the realm may be counterfeited, but the coiners must have professional skill, an appropriate location, and expensive machinery. Nor do counterfeiters ply their unholy calling except with the prospect of large gains. Certain it is that I beheld the gradual formation of the figure; that I witnessed its movements; that I received from its hand an actual flower; that I saw the figure disappear. Add to this, that the place of its disappearance was illuminated by invisible agency, in answer to an unexpressed thought of mine."

We may particularly commend to the sceptical reader's attention the very full account of the bell-ringings at Major Moor's, at Greenwich Hospital, and other places, continuing for months, and baffling all attempts to find a cause for them; to the disturbances at Lydersterne Parsonage, continued for sixty years; and to many others, none of which have ever been explained.

Mr. Owen is not content to let these matters rest (with the sceptical), or contemptuously to ignore them (with the scientific); but actually imputes them to spirits, whose agency he believes is proved by other evidence, of the nature of which we have already given some examples. This evidence, taken as a whole, proves, he thinks, that there is not habitual intercourse between the two worlds; that we seem, probably, something like apparitions to those spirits who visit us; that they often seek communion, from affection or from other motives; that they have difficulties in reaching us,—difficulties wisely interposed, because, if spiritual intercourse were as common as earthly communion, we should many of us be dissatisfied with our lot, and neglect our earthly duties. "They seek from time to time to visit us. But coming from their world of spirits, invisible to ordinary sight, inaudible by ordinary speech, how are they to make their presence known? How are they to attract our attention? In what manner does a traveller, arriving under cloud of night before a fast-closed mansion, seek to reach the in-dwellers — seek to announce his presence? Is it not by KNOCKING or RINGING?" This is our author's reply to sneers at "rapping" and "bell-ringing" phenomena.

We have devoted so much space to a sketch of Mr. Owen's book, because, in the first place, it merits notice as a literary work of a high class; and in the second, it brings prominently before us what is either the most gigantic and mysterious of delusions or the most important of truths. In either case it deserves a full and fair discussion. Neither is such a subject out of place in a scientific journal, for, in whatever light we view it, it is really a scientific question. If a fallacy or a delusion, it is of so wide-spread a nature, and influences such numbers of well-educated and even scientific men, that we have a right to demand of science a full and satisfactory exposure of it. If a truth, then it is certainly, as Mr. Owen maintains, a science of itself; a new science, and one of the most overwhelming importance in its bearings upon philosophy, history, and religion. It is now becoming almost a common thing to acknowledge that there is a certain amount of truth in the facts; with a proviso, always, of the writer's repudiation of the spiritual theory. For my own part, the only thing that makes the facts credible on evidence *is* the spiritual theory. Mr. A., or Prof. B., or Dr. C., may state that *they know* certain of the facts are true, but that all these facts can be explained without calling in the aid of spirits. Perhaps they can. But why should I, or any other reader, accept A., B., or C.'s facts, and reject Mr. Owen's, when the former are not one whit more intrinsically probable, or supported by one iota better testimony, than the latter? Yet these latter actually *force* upon us the spiritual theory, just as the facts of Geology *force* upon us the belief in long series of ancient living forms, different from those now upon the earth. I must accept all the equally well-attested facts, of equal intrinsic probability, or reject all. I cannot believe in Cretaceous fossils as realities, and reject Silurian as freaks of nature; neither can I accept the facts B. may have witnessed, and reject those of the rest of the alphabet. Yet if all the main classes of facts are admitted, the spiritual theory appears as clearly a deduction from them as the theory of extinct animals follows from the facts presented by their fossil remains. The position of the Quarterly Reviewer is, that there are no facts worth speaking of, and, therefore, no true spiritual theory can be founded on them. This is safe ground, as long as all the evidence for the facts is carefully denied, misrepresented, or ignored. But when there are ten thousand witnesses to these facts, of whom say nine thousand are as good and competent as A. or B., it is not safe ground for A. or B. to admit just so much of the facts as they have witnessed themselves, and reject the rest. The problem we have now to solve is—how much of the facts are true. Till this is done by some better test than individual experience, it is premature to discuss what theories may or may not explain them. In the meantime, let no one prejudge the question till they have studied Mr. Owen's facts and carefully weighed his arguments.

ALFRED R. WALLACE.

Spectrum Analysis in its Application to Terrestrial Substances and the Physical Constitution of the Heavenly Bodies. Familiarly explained by Dr. H. SCHELLEN. Translated from the Second Edition by JANE and CAROLINE LASSELL. Edited, with Notes, by W. HUGGINS, LL.D., D.C.L., F.R.S.

THE first edition of this work, though a valuable contribution to the literature of Spectroscopy, was not free from defects, and, although published so late as 1870, it failed to give as complete an account as could be wished of some of the more remarkable applications of spectroscopic analysis. The present edition (we refer for the moment to the German editions) has been carefully revised, and several of the sections have been enlarged and enriched, more particularly those which relate to observations of the sun. The work thus forms a sufficiently complete and tolerably exact synopsis, as well of the phenomena of spectrum analysis as of the methods by which they have been applied to the interpretation of some of the most recondite problems of nature.

Such a work well merited translation into English, and those students of spectroscopic analysis in England and America who do not read German owe thanks to the Misses Lassell for undertaking the labour of translation, and to Dr. Huggins for editing and annotating this excellent treatise.

The work is divided into three parts. The first deals with the artificial sources of high degrees of heat and light; the second, with spectrum analysis in its application to terrestrial substances; and the third, with the application of the analysis to the heavenly bodies.

We need say little about the first part of the work. It is obvious that the book would have been incomplete without an account of the chief artificial sources of light and heat; and the fifty pages devoted to the description of the Bunsen burner, the magnesium light, the oxyhydrogen flame, the lime-light, and the electric light, cannot be regarded as in excess of the requirements of the practical student of spectroscopic analysis.

With the second part we cannot express ourselves wholly satisfied. The explanation of the fundamental principles of prismatic analysis is insufficient, and even in part unsound. Indeed we cannot but notice that where Dr. Schellen approaches a subject involving mathematical considerations, his conceptions are wanting in clearness and exactness. His explanation of the "indivisibility of the pure colours of the spectrum" may be cited as an instance, and in some respects a very remarkable instance. The subject matter is obsolete, to begin with, since it relates in reality only to Newton's recognition of the fact that light from a given part of the spectrum cannot be resolved into light of other colours,—a fact of no importance in the present position of the science. But Dr. Schellen, in attempting to explain this, falls into the mistake of asserting what is untrue, though it would be unquestionably most important if true. He says, "If a small round hole be made in the screen, in any portion of the image of the spectrum,—the extreme red, for instance,*—a red ray passes through it, and appears on the opposite wall as a round spot of red light. If a second prism be interposed in the path of the ray that has passed through the screen, the ray will suffer a second refraction, and the image be thrown upon another place on the wall: this new image, however, is simply red like the incident ray, *and by a careful adjustment of the prism shows no elongation, but appears perfectly round.*" This, of course, is utterly erroneous; were it true, our spectroscopists would gain nothing by employing more than a single prism in any of their researches. In extending the reasoning, Dr. Schellen introduces a figure representing the action of a second prism on the central colour of the spectrum; but in *this* figure the second prism is so placed as to reverse the action of the first, the contrary being the case in the figure illustrating the former part of his reasoning. In the case illustrated by the second figure a round spot of light would naturally be obtained, the second prism restoring to parallelism the rays which the first prism had caused to diverge.

But although in dealing with theoretical considerations Schellen is thus not unfrequently inexact, the description of the practical details of spectroscopic analysis is in nearly every instance trustworthy; while in the few instances where there is room for questioning Dr. Schellen's accuracy, the editor supplies, in a foot-note, the necessary emendation. The latter portion of Part II., in which the various orders of spectra are described, and the application of the analysis to the investigation of terrestrial substances is considered, becomes thus exceptionally valuable; for to Schellen's own familiarity with the subject, and his careful study of the labours of Bunsen, Kirchhoff, Thalén, and other continental spectroscopists, is superadded Dr. Huggins's independent mastery of this department of the new science. And we cannot but notice here how little acquaintance with the history of spectroscopic analysis is displayed by those who suppose that Dr. Huggins's application of the analysis to the heavenly bodies includes the whole of his labours as a spectroscopist. We would invite those who entertain this opinion to the study of Dr. Watts's useful treatise, the "Index of Spectra," noting that all the work by Huggins recorded and tabulated in that work preceded those astronomical labours which have been regarded as justly entitling him to be called the Herschel of the Spectroscope.

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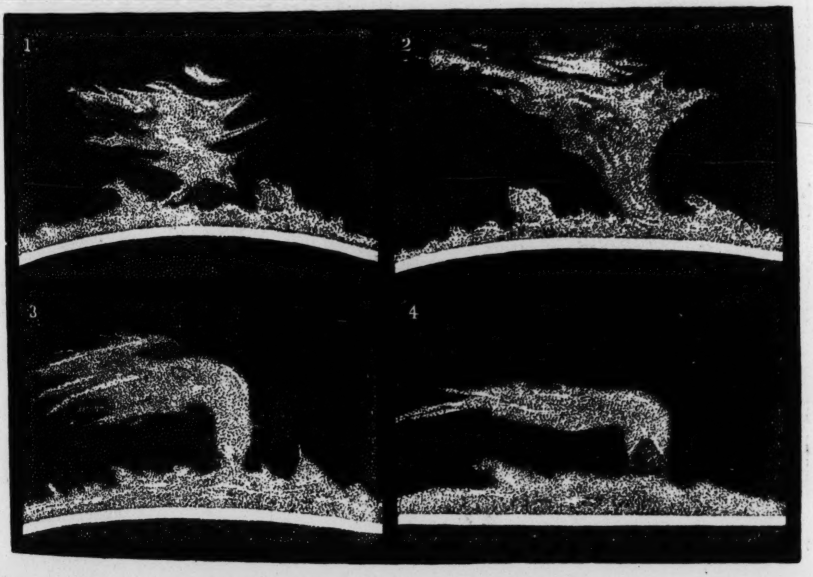
* The reference in the text is to Fig. 28. It should be Fig. 32, as will appear by a reference to the first German edition.

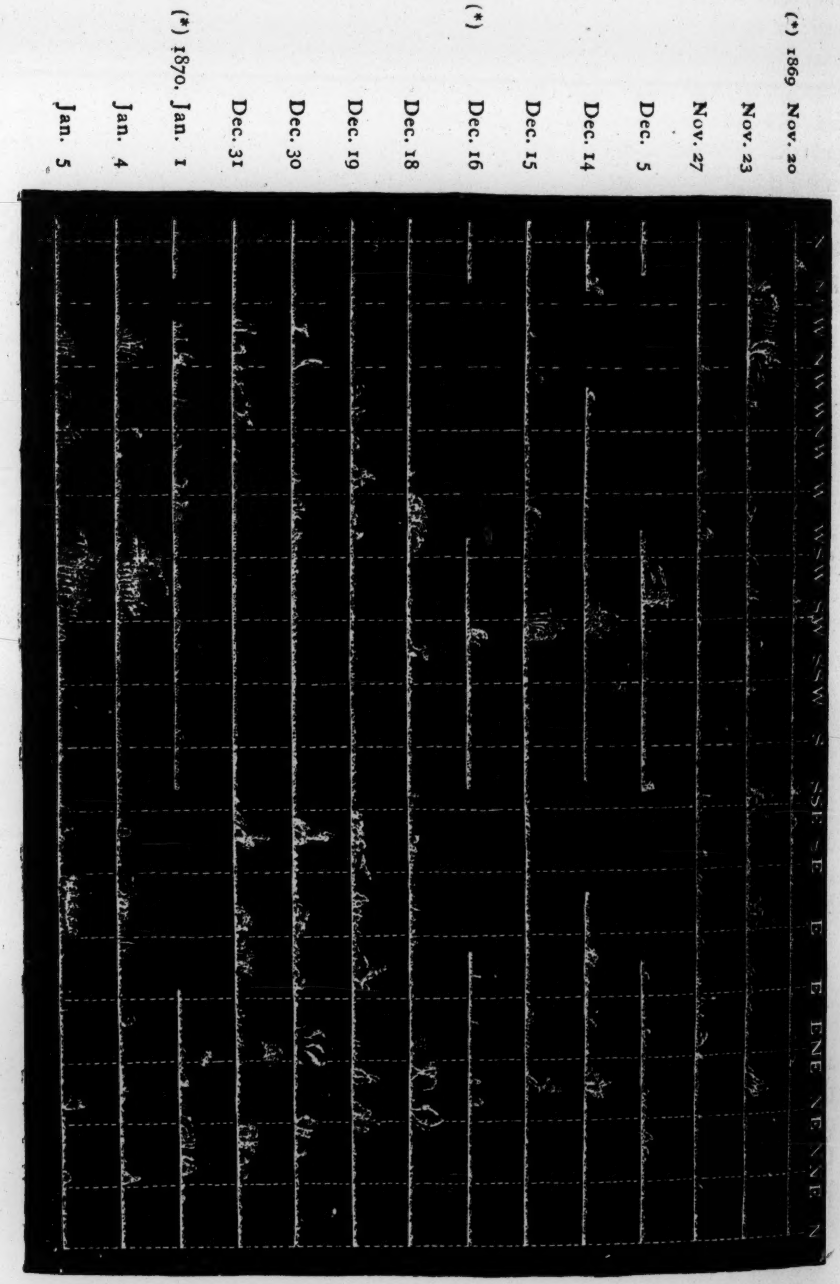
IG. 17,



Changes in the form of a Prominence.

Before passing to the consideration of the last part of Schellen's work, we would invite attention to the extreme interest of those spectroscopic researches whose difficulty depends on the minuteness of the quantity of matter placed under analysis. If our wonder is excited when we see a Huggins or Secchi obtaining, from beyond the immeasurable distances which separate us from the stars, information respecting the structure of those orbs, we have equal reason to contemplate with interest the re-

FIG. 18.



Respighi's observations of the Prominences round the entire limb of the Sun.

cognition of the existence of the 10,000th part of a grain of some element in solution, or of yet minuter portions, by the use of the induction spark,[*] or the discovery, by this potent means of analysis, of elements which had previously escaped recognition.

The third part of the work occupies two-thirds of the volume. The sections treating of the solar spectrum and its lines are well written, and being illustrated by reduced copies of Kirchhoff's maps and scale, and of Angström's and Thalén's maps with wave-length scales, are of great value to the student of practical spectroscopy. A sufficient account is also given of the atmospheric lines which make their appearance in the solar spectrum when the sun is near the horizon.

Schellen passes thence to the consideration of the solar spots, and, having remarked that it would lead him too far from his subject to dwell on their phenomena, naturally proceeds to supply about a score of pages of descriptive matter, for which the reader might very well have been referred to astronomical treatises. The discussion of the spectra of spots and faculæ, which follows, is full and satisfactory, save that Schellen places rather more reliance on Secchi's observations, and especially on his asserted recognition of the presence of aqueous vapour in the solar spots, than we believe to be justified by the evidence. Secchi, on one occasion, could recognise the bands of aqueous vapour, due to the passage of a cloud over the sun, more clearly in the vicinity of spots than elsewhere on the solar disc, and therefore somewhat hastily concluded "that the absorptive power in the sun producing these bands is intensified by the absorptive action of the aqueous vapour contained in the earth's atmosphere; and that the cause of the absorption in the sun in the neighbourhood of the solar spots is therefore the same as that which is present in a fog, namely, aqueous vapour." It does not seem to have occurred to him that the general absorption in the spot spectrum would render the atmospheric bands apparently more distinct in that spectrum, without any increase in the real darkness of those particular bands. The editor remarks, very justly, that Secchi's result appears to him to need confirmation; and we could even have wished that he had more pointedly indicated the fallacy in Secchi's reasoning.

The phenomena of solar eclipses are treated very fully, and in a very interesting manner. The sections relating to this part of the subject are also abundantly illustrated. We speak of the phenomena of eclipses as including the prominences and sierra, though in reality the most valuable observations of the last-named phenomena have been made when the sun has not been eclipsed. In dealing with the history of the method by which this has been accomplished, Dr. Schellen falls into some mistakes which are corrected by the editor. In particular, it is to be noticed that Schellen fails to ascribe the open slit method, by which the actual figures of the prominences can be studied whenever the sun is visible, to Zöllner and Huggins, who independently enunciated the method—Huggins accompanying his paper with an account of the first successful observation of a prominence by this method. The coloured illustrations of this part of the subject are very beautiful, and add largely to the value of the treatise. They include views by Zöllner, Respighi, and Young, the coloured views by the two last-named observers being now published in England for the first time we believe. The accompanying figures (17 and 18), though instructive, afford but a faint idea of the weird beauty of the enlarged coloured drawings of particular prominences.

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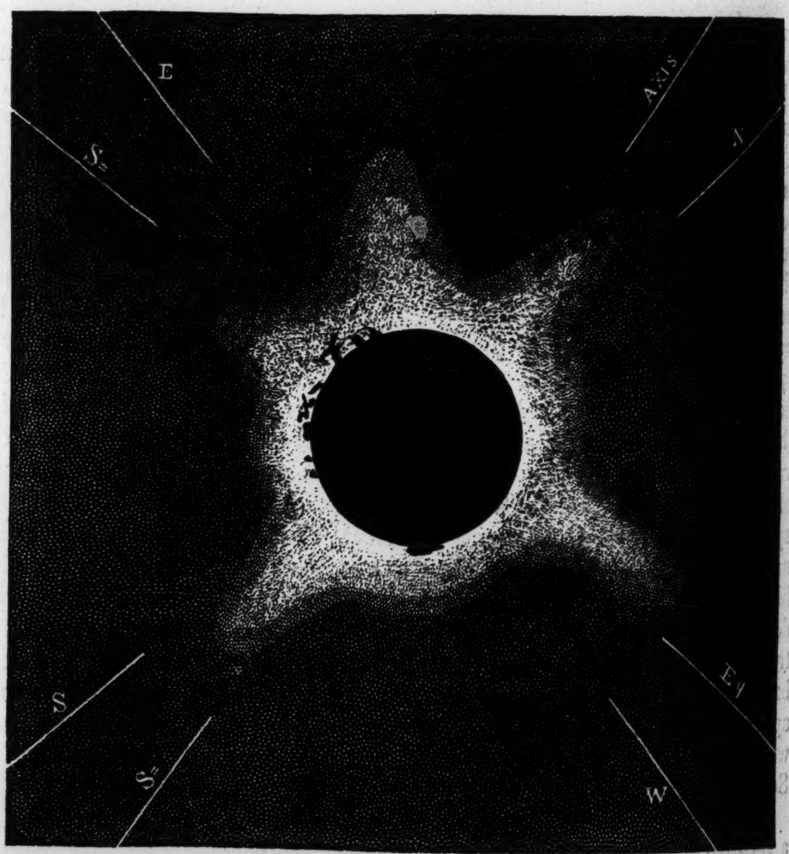
[*] In this way the 100,000,000th of a milligramme of strontium, or the 80,000,000th of a grain of Crookes's new element, thallium, can be made to reveal its presence.

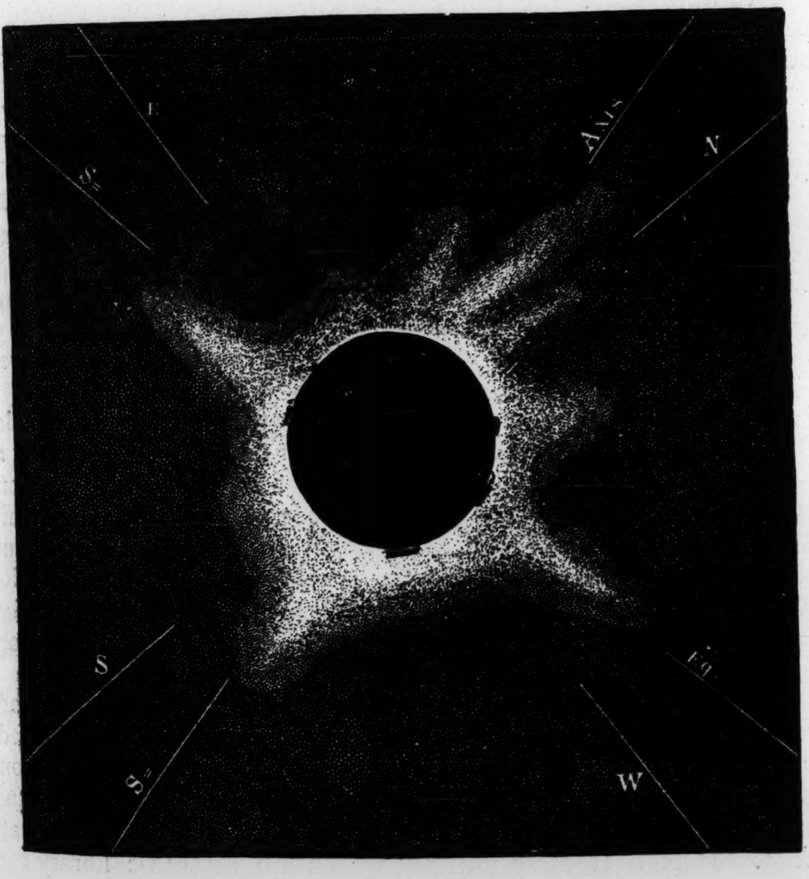
Fig. 19.



Gould's Drawing of the Corona, August 7, 1869. (4h. 58m.)

In dealing with the corona (a subject which he somewhat unhappily intermixes with the treatment of the prominences) Schellen merely sums up without submitting to analysis the evidence which had reached him. Accordingly he arrives at no definite conclusion on the question whether the corona is a solar or terrestrial phenomenon. The extract given by the editor from the Report of the Council of the Astronomical Society appears to us, we must admit, to be scarcely more satisfactory, since it speaks of theories as admissible which could not at the time be possibly entertained in the presence of evidence already available. Of course after the results of the recent eclipse all the doubts thus expressed must be regarded as definitely disposed of; the reality of the corona, even to its utmost visible limits, as a solar appendage of wonderful extent and complexity, being now admitted by all. But it is worthy of notice in this place how feeble had been the evidence on account of which the true theory of the corona was so long disputed. The difficulty of delineating an object so delicate, and the consequent differences between pictures taken by different observers at different places, and under different atmospheric conditions,—changes supposed to have been recognised by one and the same observer,—and imagined differences between photographic pictures really resembling each

FIG. 20.



Gould's Drawing of the Corona, August 7, 1869. (5h.)

other very closely,—such was the evidence urged against the long array of facts pointing the other way.

As respects the second point, we may illustrate the nature of the evidence, by showing the two drawings, Figs. 19 and 20, by Dr. Gould on which chief stress was laid by the advocates of the atmospheric glare theory. It will scarcely be believed that the differences between these drawings (differences which are so readily explained by the changes of condition to which the air was subjected *through which* a solar corona must necessarily be seen, as well as by the changing power of the eye to appreciate the outer faint coronal light) were urged as demonstrative of the fact that the corona is a phenomenon of our own atmosphere!

As respects the third point above referred to, it is necessary to point out that the argument relating to the photographs by Lord Lindsay and Mr. Brothers (pp. 372, 373 of the present work) is vitiated by the circumstance that in some unexplained way Lord Lindsay's photograph was inverted. The perfect agreement between the prominences shown in all the photographs when Lord Lindsay's picture is re-inverted abundantly proves this, and thus the supposed discrepancy between a photograph taken at the beginning and one taken at the end of totality has no real existence.

The sections of the work relating to the fixed stars, nebulæ, and comets, are extremely interesting, and may be accepted as fairly presenting the present position of the subject,—with one exception only, that undue prominence is given to Father Secchi's study of star spectra. Of the section on meteors we find ourselves unable to speak altogether with approval. Dr. Schellen does not sufficiently distinguish between the points which have been demonstrated and those which remain matters of speculation. Nor is the history of the subject quite accurately rendered.

However, such blemishes as these do not importantly detract from the value of Schellen's excellent treatise. It could, indeed, scarcely be expected that so large a volume should be free from some defects; and, on the whole, the work before us is as sound and trustworthy as it is wide in range and exhaustive in treatment. It is a treatise without which no scientific library can be regarded as complete. The work of translation has been accomplished carefully, and all things considered, satisfactorily. Here and there occur passages which appear to us somewhat cumbersome, a fault chiefly due, we believe, to the anxiety of the translators to follow their author as closely as possible. But such passages are few and far between; and, apart from its scientific value, the book is very readable. The editorial notes greatly enhance its value.

Elementary Treatise on Natural Philosophy. By A. PRIVAT DESCHANEL, Inspector of the Academy of Paris. Translated and Edited by J. D. EVERETT, M.A., D.C.L., &c., Professor of Natural Philosophy in Queen's College, Belfast. In four Parts: Part III. Electricity and Magnetism. London: Blackie and Son. 1872.

THIS part of the translation of M. Deschanel's "Traité Elementaire de Physique" may be considered as the masterpiece of Professor Everett's series of three volumes now before the public. French writers appear to be but very slightly acquainted

FIG. 21.

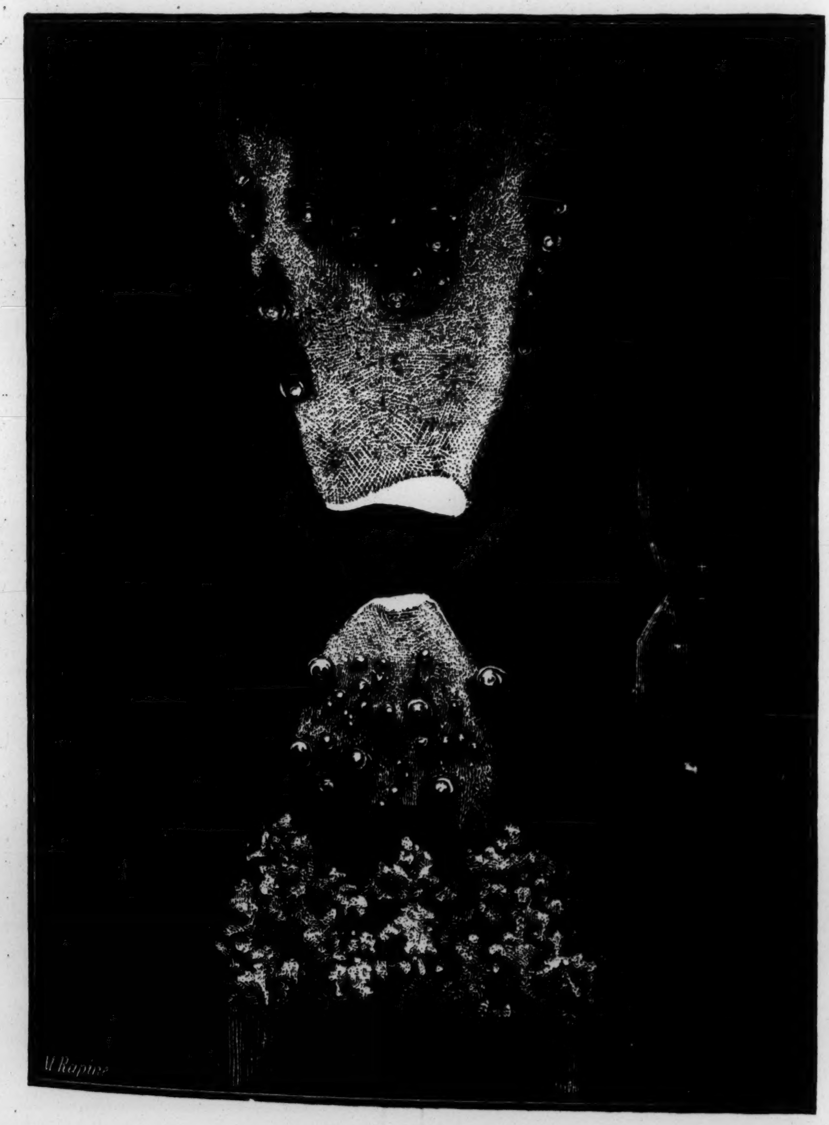


Image of the Carbon Points.

with the researches of Faraday in electro-magnetism, and of Sir William Thomson in general electric principles. There has therefore been much to add, and Dr. Everett is to be congratulated on his happy method of collating the experiments necessary to an English work. The description of the various forms of electrometers, for instance, leaves nothing to be desired.

We must again commend the illustrations, and express our indebtedness to Messrs. Blackie and Sons for being able to lay before our readers a specimen of the exquisite woodcuts. The one selected exhibits the image of the carbon points of the electric lamp as viewed through a lens, the natural size of the carbons being indicated by the sketch at the right hand. The book is well bound in limp cloth covers, a style of binding every student will appreciate.

Experimental Mechanics. By ROBERT STAWELL BALL, A.M, Professor of Applied Mathematics and Mechanism in the Royal College of Science for Ireland (Science and Art Department). London and New York: Macmillan and Co. 1871.

THIS volume contains the substance of a series of twenty evening lectures upon "Experimental Mechanics" delivered by the Author at the Royal College of Science for Ireland. The aim has been to create in the mind of the student physical ideas corresponding to theoretical laws, and thus to produce a work which may be regarded either as a supplement or an introduction to manuals of theoretical mechanics. We cannot praise the attempt too highly, nor congratulate Professor Ball too sincerely upon his success. The laws of mechanics are essentially simple, and in this work they meet with an appropriate exposition. No complicated formulæ are introduced into the calculations, numerical or geometrical illustration being chiefly employed. The method of treatment of the laws relating to friction, to the mechanical powers, to the strength of timber and structures, to the pendulum and to the laws of motion, is original and extremely explicit. But it must not be misunderstood that the work is too simple for the advanced student,—far from it. Mr. Ball has well distinguished between the class of students who know mathematics and those who do not. Therefore we can safely recommend the book to the notice of all.

PROGRESS IN SCIENCE.

MINING.

One of the most important branches of enquiry undertaken by the Royal Coal Commission related to the statistics of the production, consumption, and export, of our mineral fuel. The labour of this enquiry—which is represented by the third volume of the Report, consisting of 500 pages—devolved almost exclusively upon Mr. Robert Hunt, F.R.S., the share taken by the late Sir R. Murchison being merely nominal. In consequence of this additional work, followed as it unhappily was by a return of illness, the Keeper of Mining Records was unable to issue his annual volume of "Mineral Statistics" last year. During the past quarter, however, the official returns have been published,[*] and we hence learn the amount and value of the minerals raised in the United Kingdom in 1870. According to our usual custom, we here present a general summary of these statistics:—

	Tons.	£
Coal	110,431,192	27,607,798
Iron ore	14,370,654	4,951,220
Copper ore	106,698	437,851
Tin ore	15,234	1,002,357
Lead ore	98,176	1,200,209
Zinc ore	13,586	41,058
Iron pyrites (sulphur ore) ..	58,428	36,026
Arsenic[†]	4,050	17,739
Gossans, ochres, &c.	4,844	4,261
Wolfram and tungstate of soda	51	653
Manganese	4,838	19,499
Nickel	½	27
Barytes	6,515	3,771
Clays, fine and fire (estimated)	1,200,000	450,000
Earthy minerals, various (do.)	—	575,000
Salt	1,489,450	744,725
Coprolites (estimated) ..	35,000	50,000
Total value		£37,142,194

In discussing these figures, Mr. Hunt calls attention to the increase in the production of coal, the produce of 1870 having exceeded that of the previous year by upwards of *three millions* of tons. The great activity in the iron trade caused the consumption of a large proportion of this additional coal, but at the same time our exports were increased.

With the statistics of our own coal production it is interesting to compare that of the United States. From the American official returns for 1870 we learn that during that year the total production of coal of all kinds amounted to 34,600,461 tons. Of this quantity 15,368,437 tons consisted of anthracite and semi-anthracite which had been sent to market, and 3,842,876 tons of similar fuels retained for home consumption. The bituminous coal sold amounted to only 4,589,148 tons, and even out of this quantity 420,683 tons had been imported; but, in addition to what found its way into the market, it is estimated that 10,800,000 tons of bituminous coal were mined and consumed in the United States, without being included in the tabular returns. The statistics further show that, in the great coal-producing counties of

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[*] Mineral Statistics of the United Kingdom of Great Britain and Ireland, for the year 1870. With an Appendix. By Robert Hunt, F.R.S., Keeper of Mining Records. London: Longmans, and Stanford. 1872.

[†] Nearly 2000 tons of this arsenic will have been obtained from the burning-houses on the tin mines. A considerable quantity is produced at Swansea, of which no return has been obtainable.

Schuylkill, Northumberland, Columbia, and Dauphin, 129 fatal accidents occurred during the year, but it is notable that only *six* of these deaths resulted from explosions of fire-damp.

At a recent meeting of the Wigan Field Naturalists' Society, Mr. Perrins read a paper on the probable duration of the important coal-field of Wigan. Coming from one of the leading mining surveyors of the town, Mr. Perrins's estimate deserves attention. For the purpose of his enquiry he considers that the coal-field occupies an area embraced within a radius of two miles from the parish church. In this district there are about twelve workable coal-seams, and the author describes the geological features of each of these in succession. He divides the field into a number of belts, each of which is separately examined, and its yield of coal estimated. We pass over these details, however, and arrive at once at the aggregate result. The whole of the Wigan coal-field originally contained an amount of mineral computed at 231,810,000 tons. Of this quantity 96,285,000 tons have already been removed, thus leaving 135,525,000 tons still underground. At the present rate of working about 2,000,000 tons are removed annually; and assuming this rate to continue, without increase or diminution, the Wigan coal-field will be exhausted in little more than fifty years. Seeing that these collieries employ, directly and indirectly, about 7000 men, the gradual diminution of the coal must have a serious social influence upon the locality. It is cheering, however, to remember that the iron trade around Wigan has of late received a great impetus, and it is therefore to be hoped that the development of this industry may compensate for the decline of the coal trade.

A successful trial of Mr. G. L. Scott's recently-patented steam-ventilator has been made at the Lower Moor Colliery, at Oldham, where a 4-feet seam of coal, faulted in all directions, is worked by intricate galleries extending for a distance of a mile from the shaft, the shaft being 888 feet in depth. A brick chamber, in communication with the upcast shaft, is covered by perforated iron plates carrying 72 vertical cast-iron pipes, each about 5 feet in length and 7 inches in internal diameter. Inside each of these pipes is a small vertical steam pipe, which terminates by an orifice, $\frac{3}{16}$ths of an inch in diameter, at about 2 feet below the top of the larger pipe. The system of pipes forms a rectangular arrangement occupying a space about 10 feet square, and is supplied with steam by a 4-inch pipe from the boilers of the winding and pumping engine. The results obtained by the use of this simple steam-ventilator compare favourably with those of the old furnace system, but it was not considered necessary, at the trial in question, to test the full power of the new apparatus. It is almost needless, however, to state that any ventilator which—like this steam apparatus—can be placed at the surface, so as to be under complete control, must possess great advantages over the ordinary system of ventilation, in which the apparatus is lodged in the pit itself.

To prevent accidents from over-winding in mine-shafts, an ingenious apparatus has been patented by Mr. W. Walker. The load to be raised is carried by chains or ropes attached to the lower ends of two curved metal levers, hinged together in the middle, and connected above with the winding-rope or chain. These levers are so constructed that when the load is being raised their lower ends diverge, whilst the upper extremities remain closed together, and hold the winding-rope between them. On the other hand, if the levers turn upon their common hinge, the lower parts are brought together, and the upper ends open out so as to release the rope. At that point which forms a limit to the raising of the load, and beyond which it would be dangerous to wind, there is a fixed beam, with an aperture sufficiently large to admit the winding-rope and the head of the safety apparatus. In the event of over-winding, the upper parts of the levers pass through this aperture, but the rest of the apparatus is arrested by a guard-plate, or collar, which is placed over the levers, and comes in contact with the under side of the beam. As the load now tends to rise, the distended ends of the levers are brought together by pressure against the sides of a slot in the collar, and as the lower ends of the levers come together, the upper parts forming the head fall apart, and rest upon the top of the beam so as to support the load, whilst the released rope is carried upwards by the continued winding.

Through the Geological Society of London, Mr. G. Milner Stephen, of Sydney, announces the recent discovery of a very valuable deposit of tin ore in New South Wales. The ore occurs in crystals and rolled fragments, in beds of conglomerate and in granite. It appears that the deposit extends over an area of several miles in the district of New England.

From the same authority we learn that a party of four men, induced by the offer of a reward by the French Government, have discovered gold on the banks of the River Bondé, on the N.E. coast of New Caledonia. Hitherto only auriferous drift has been found, but it is expected that quartz reefs will soon be discovered.

In a paper "On Gossans," by Mr. W. Argall, of Great Huel Vor, recently read before the Miners' Association of Cornwall and Devon, the author suggested that a collection of these products might advantageously be preserved for reference in some central museum, the collection being accompanied by analyses of the specimens and records of the conditions under which they occurred. Remembering the great value set by miners upon the occurrence of gossan as superficial indications of mineral deposits beneath, the suggestion seems to be worthy of notice. Unfortunately, however, these gossans are rather unattractive to the eye, consisting as they generally do of ochreous oxide of iron mixed with cellular quartz; the result, in fact, of the alteration of the upper part of the ore by atmospheric and other influences. Some of the richest deposits, especially copper lodes, bear masses of this unsightly gossan on the outcrop, or "back," of the vein; and Continental miners, not less than Cornishmen, attach great importance to the occurrence of this *Chapeau de Fer*, or *Eiserne Hut*, as likely to betoken the existence of a productive vein of ore. A collection of gossans, chiefly Cornish, has for many years past been exhibited in the Museum of Practical Geology.

With the opening of the new year there appeared a new monthly magazine devoted to the mining interest of this country. Under the editorship of Mr. Nelson Boyd, F.G.S., the "Mining Magazine and Review" promises to become a technical journal of much value to those engaged in mining, quarrying, metallurgy, and kindred pursuits. The three numbers already issued contain many interesting articles bearing upon these branches of industry.

METALLURGY.

Our chronicles last quarter contained a brief account of Danks's rotary furnace for puddling iron by machinery. Soon after the publication of that number, Messrs. Jones, Snelus, and Lester, the three Commissioners appointed by the Puddling Committee of the Iron and Steel Institute, having returned from their visit to the United States, issued their Report. This Report has been published in the Journal of the Institute, and contains an elaborate description of the furnace, details of the mode of fettling, the consumption of fuel, and the quality of the iron produced. The visit of the Commissioners has convinced them that the process can be successfully carried out, and that even in its present state it offers commercial advantages over hand-puddling. At the same time they believe that the process is only yet in its infancy, and is capable of rapid development. Materials were taken out from this country to be experimented upon in the presence of the Commissioners, and samples of the fettling materials and of the iron produced in the furnace have been brought home. It has been arranged with the inventor that the royalty to be paid in Great Britain shall not exceed two shillings per ton on machine-made puddled iron.

We learn from the "Mining Journal" that an improved furnace for puddling iron by machinery, the invention of Mr. A. Spencer, has recently been at work, with the most encouraging results, at the West Hartlepool Iron Works. Spencer's revolving furnace is a box-like vessel, of square or rhomboidal transverse section, furnished with circular ends having apertures through which a communication is established with the fire-grate on the one hand and the chimney on the other. The sides are built up of a number of flanged plates, bolted together into a polygonal form, and cast with honeycombed or cellular sides so as to form cavities for receiving and securely holding the fettling with which the converter is lined. This fettling consists chiefly of mill-furnace cinder, or ball-furnace tap; and having been melted in a cupola furnace, is either run directly into the converter or moulded into masses, which when cold fit the cavities in the sides. When the molten charge of cast-iron has been introduced into the converter, the charging-holes are closed, and the vessel is caused to revolve by means of large spur-wheels attached to the end-plates: the liquid metal becomes rapidly agitated against the flat sides, and in about half an hour the balls of wrought-iron may be removed, at least 6 cwts. of metal being turned out at each heat.

Some improvements in mechanical puddling-furnaces have also been lately suggested by Mr. W. Ferrie, of the Monklands Iron Works. He causes the movable bed or hearth of the furnace to revolve by fixing to it a cylindrical flange which projects downwards into a circular gutter filled with water, sand, or ground fire-brick, by which means a connection is sealed between the fixed and the moving parts of the furnace, without interfering with the freedom of motion.

An elaborate essay on the Metallurgy of Silver in Mexico, by M. P. Laur, has been published in two recent numbers of the "Annales des Mines." After noticing the mode of occurrence of the ores, the author describes in detail the several metallurgical processes used at the different works,—namely, amalgamation at ordinary temperatures by the *patio* process; amalgamation in the *cazo*, or vessel containing a boiling solution of common salt; and the old Saxon process of amalgamation with iron in rotating barrels. M. Laur raises many objections to the generally-received theory of amalgamation by the *patio* process, and advances an original view of the reactions which occur in the *patio*. It may be well to state that the *torta*, or heap of materials used in the reduction of the silver ores by this method, consists essentially of a mixture of common salt, "magistral" or roasted copper pyrites, mercury, and silver ores usually in the state of sulphides. According to most metallurgical chemists, the chloride of sodium and the sulphate of copper in the magistral react upon each other, and thus produce sulphate of soda and chloride of copper: this chloride then converts the sulphide of silver into a chloride, which dissolves in the salt water present in the *torta*; the mercury then rapidly attacks the solution of chloride of silver, reducing the metal and becoming in turn converted into calomel, whilst the free silver forms, with some of the unaltered mercury, an amalgam, which is retorted, and the mercury distilled off while the silver remains behind. Modifications of this theory have been proposed, but the essential points remain—that the silver is formed into a chloride, and this is decomposed by the mercury. M. Laur's Mexican experience leads him to believe, on the contrary, that the sulphide of silver is reduced *directly* to the metallic state, and does not pass through the intermediate condition of a chloride. By the reaction of the magistral with the salt, sulphate of soda and protochloride of copper are formed:—

$$NaCl + CuO.SO_3 = NaO.SO_3 + CuCl.$$

This chloride is then reduced to the state of a sub-salt, which combines with the sodium chloride to form a double salt—

$$2CuCl + NaCl + Hg = NaCl.Cu_2Cl + HgCl.$$

The double salt reacts directly upon the silver sulphide, and effects its reduction:—

$$NaCl.Cu_2Cl + AgS = NaCl.CuCl + CuS + Ag.$$

The protochloride of copper passes again to the state of subchloride, while the sulphide of copper is oxidised into sulphate, and the cycle of change thus commences afresh.

Messrs. Hargreaves and Robinson, of Widnes, have patented certain improvements in the method of treating metallic sulphides, especially pyrites, by which they are made to yield the greatest amount of sulphur, and are then converted into chlorides. The pyrites is first roasted in a series of tall vertical retorts, so arranged that each becomes in turn the first, intermediate, and last vessel of the set, with respect to the passage of air or gas through the series. A current of chlorine or of hydrochloric acid gas is passed through the spent pyrites contained in these retorts and maintained at a high temperature.

Other improvements in roasting pyrites have been patented by Messrs. Perret Brothers and Olivier, of Paris. The heat generated in the furnace in which the crude pyrites is roasted is conducted into another furnace, where it is utilised in further roasting the ore, so as to drive off the sulphur more completely. The operations may be conducted in a single furnace, built with several floors, through which the heat circulates.

From Mr. Hunt's volume of "Mineral Statistics" for 1870 we are able to extract the following table, showing the quantities and value of the metals obtained from the ores raised in the United Kingdom during that year:—

		£
Pig-iron	5,963,515 tons.	14,908,787
Tin..	10,200 „	1,299,505
Copper	7,175 „	551,309
Lead	73,420 „	1,452,715
Zinc	3,936 „	74,096
Silver	784,562 ozs.	196,140
Gold	191 „	750
Other metals (estimated) ..	—	3,500
		£18,486,802

MINERALOGY.

Among a number of "Mineralogical Communications" recently made by Prof. Vom Rath to "Poggendorff's Annalen," perhaps the most interesting are those which relate to the constitution of the felspars. Several lime-soda felspars have been carefully examined, including specimens of andesine from Vesuvius, Frejus, and Predazzo; of oligoclase from Nieder-mendig and Veltlin; and of labradorite from Iceland. These studies confirm Tschermak's views regarding the composition of the lime-soda series, and tend to show that these so-called species may all be represented as isomorphous mixtures of albite, or pure soda felspar, and anorthite, or pure lime felspar. Hence we can never expect to find an oligoclase quite free from lime, or a labradorite free from soda. It has indeed been supposed that the mineral called *Ersbyite* represents a labradorite without soda, but Vom Rath's investigations show that this species cannot be referred to labradorite, but should rather be placed with scapolite.

In a former number of this Journal allusion was made to the discovery of crystals of *boracite* in the salt-mines of Stassfurt, in Prussian Saxony. These crystals have since been described by Dr. Schultze, from whom we learn that they were found among the residual matters obtained from the treatment of salts which had been raised from the upper beds of these great deposits, and had been lixiviated in the chloride of potassium works at Stassfurt. The author offers some theoretical views on the probable origin of this boracite, and the formation of certain nodules containing alternating layers of boracite and other minerals. The double sulphate of soda and magnesia, termed *Simonyite*, has been found in the Anhalt portion of these salt-mines. Simonyite contains $NaO.SO_3+MgO.SO_3+4HO$; and the sulphate of soda present in the salt may render it of economic value in the manufacture of carbonate of soda.

Julianite is the name proposed by Prof. Websky for a new species somewhat resembling fahlerz, but possessing isomorphous relations with buntkupfererz. It occurs in small groups of cubic crystals, presenting a dark grey colour, and containing $As_2Cu_3S_6$, part of the arsenic being replaced by antimony and iron, and part of the copper by silver. The ore was formerly found in the Friederike-Juliane Mine, at Rudelstadt, in Silesia.

Under the name of *Beyrichite*, Prof. Liebe describes a new species from the Westerwald. It is found in groups of macled prisms, of a lead-gray colour, with a faint metallic lustre. Its composition may be formulated as $3NiS.2NiS_2$; but the mineral contains a variable proportion of iron, which, in this calculation, is supposed to replace the nickel: if the iron, however, be due to the presence of iron pyrites, the formula of Beyrichite becomes $2NiS.NiS_2$.

A native silicate, hitherto undescribed, has received from Herr Frenzel the name of *Bismuthoferrite*. It occurs, with a variety of hypochlorite, at Schneeberg, in Saxony, and contains $Bi_2O_3.2Fe_2O_3.4SiO_2$.

Trögerite and *Walpurgine* are two new species, of which preliminary notices have been lately published by Weisbach, of Freiberg. Both are arseniates of uranium from Schneeberg, but the composition of the former may be represented as $5Ur_2O_3.2AsO_5+20HO$, whilst that of the latter coincides with the following formula:—$(5Bi_2O_3.3Ur_2O_3)2AsO_5+10HO$.

Some little time back a new fluo-phosphate of alumina was described by MM. Des Cloizeaux and Moissenet. As the mineral came from the tin-mines of Montebras, in Central France, it received the distinctive name of *Montebrasite*. The substance occurs abundantly in parts of the gangue of these veins, and is accompanied by fluor-spar, apatite, chalcolite, wavellite, and turquois. Its analysis led to the following formula:—$2(Al_2F_3.3MF)+4Al_2O_3.3PO_5$. M. Pisani, not satisfied with its determination as a distinct species, has lately examined the mineral afresh, and from his analysis declares it to be identical with the mineral known as Amblygonite. It appears, then, that the mineral of Montebras does not possess characters sufficiently diagnostic to entitle it to take rank as a distinct species; but, nevertheless, the discovery of so rare a mineral as amblygonite in large quantity in these mines is a matter of much mineralogical interest.

Dr. Streng announces the discovery of *Tridymite* (Vom Rath's species of silica) in an orthoclase porphyry near Waldbökelheim, where it occurs in crystals of similar form to those found in trachytic rocks.

Some zeolitic minerals from the dolerites of the Bergonne limestone have been described by M. Gonnard. The dolerite is strongly magnetic, and certain specimens exhibit marked polarity. Where the rock becomes amygdaloidal the cavities contain zeolites, of which three are here specialised—namely, *mesole*, in globules of dull white colour; *christianite*, not the felspar so named by Montecelli; and the variety of chabazite known as *phacolite*.

The Greenland meteorites noticed in the last number of this Journal have been made the subject of a further communication to the Geological Society, in which Prof. Nordenskjöld describes carefully the conditions under which the masses of iron occur at Ofivak, and also gives analyses of the metal. A portion of one of the largest blocks yielded—Iron, 84·49; nickel, 2·48; cobalt, 0·07; copper, 0·27; magnesia, 0·04; sulphur, 1·52; phosphorus, 0·20; chlorine, 0·72; organic matter, water, and loss, 10·16. Nordenskjöld adheres to his opinion that these remarkable masses of metal are genuine meteorites.

Success continues to attend the diamond workings in South Africa. At present the most active operations are going on at the "New Rush," on the Colesberg Koppie. Mr. Gilfillan has just returned to this country with some remarkably fine diamonds, accompanied by samples of the associated rocks and detrital matter. We have had an opportunity of examining these specimens, and believe that the results of Mr. Gilfillan's observations on the conditions under which the diamonds are found will shortly be communicated to the Geological Society.

ENGINEERING—CIVIL AND MECHANICAL.

Guns.—In our last quarter's chronicles reference was made to a crack which had been discovered in the lining of the new 35-ton gun known as the "Woolwich Infant." Three theories have been advanced to account for this internal injury, which were recently stated by Capt. Dawson, R.N., in a lecture on Guns, at Plymouth. The first theory is, that the bottom stud, flattened by the blow above the shot caused by the escaping gas, overrode the groove, causing a squeeze which delayed its exit, and led to an accumulation of gas in the powder-chamber. 2nd. That the wabble caused by balancing the shot on two studs, and the irregular action of the powder above it, due to the non-centreing of the shot, wrenched out or sheered off the stud, and set up a motion of the shot across the bore, which enhanced the difficulty of its escape. 3rd. That pebble powder developed some new quality, when ignited in 120-lb. charges, which it did not possess when fired in quantities of 100 lbs. and under. Captain Dawson is evidently of opinion that the Woolwich system of rifling is one of the primary defects in this new gun, and that the injuries were attributable to the vicious system of grooving on an increasing twist, which necessitated the concentration of rotary effort on a single row of studs incapable of giving adequate rotation with the present amount of spiral, and this angle of spiral could not be increased, because the studs would not endure the extra effort, but would be sheered off, and cease to act at all. Contrasting other long iron bearing systems which had undergone official trial with the present short bearings, Capt. Dawson showed that, whilst the whole effort of rotating a 700-lb. shell was now thrown upon a total of 5½ inches of stud bearing, it would under the Scott iron flange system be diffused over 13 feet of bearing; and that this latter system had narrower shallower grooves, which took only one-fourth the quantity of metal out of the gun, and therefore made less space for escaping gases to erode the bore; whilst, instead of the lower groove being spiked by its own stud, Scott's iron flange would receive the shock on a rib 22½ inches long. In the trial between two 7½-ton guns on this system, the Woolwich rifled gun was declared incapable of further firing, except "under precautions" against bursting, whilst the grooves and lands of Scott's gun were perfectly uninjured. Yet Scott's guns gave the greatest hitting power at the muzzle, and projected its shot 1500 yards with 2 degrees of elevation, using 20 lbs. of powder, whilst the Woolwich one required 25 lbs. to reach the same distance. Comparing the work done by the respective projectiles, the Scott iron bearing 110-lb. shot escaped from its charge so much more easily than its studded rival, that—though the conditions were exactly alike in all else—the Scott hit a muzzle blow 133 foot-tons heavier than the French projectile, and no less than 260 foot-tons more powerful than that of the present 7-inch gun, the charges of which have to be reduced to make amends for its lack of endurance.

Navigable Balloon.—The experimental balloon recently constructed by the French Government, upon M. Dupuy de Lôme's system, rose from the court-yard of the Fort Neuf. at Vincennes, on the 2nd of February last, having on board MM. Dupuy de Lôme, Lédè (Engineer in the Marine), Yon, and Dartois (aërostats), and ten other persons, forming altogether a total of fourteen men. The construction of this aërial machine starts with the principle that, in order to obtain a navigable balloon, its permanence of form must be maintained without any sensible undulation of surface, and a horizontal axis of least resistance must be obtained in a direction parallel to the propelling force. The permanence of form is assured by a fan carried in the car, and put in communication by a tube, with a small balloon placed within the large one at its lowest part. The volume of this small balloon is one-tenth of that of the large one. It is furnished with a valve opening both within and without, and regulated by springs. The large balloon is provided with two hanging tubes open to the air, and falling for a distance of 25 feet from the lower part of the balloon. The inflation of the little balloon causes the hydrogen to fall more or less in the hanging tubes, but never sufficiently to force it out of their open ends. To obtain a horizontal plane of least resistance, the form given to the balloon was that developed by the arc of a circle turning round its chord, and in which the versed sine was nearly one-fifth of the length of the chord. The extreme total length of the balloon is 118 feet 6 inches; its greatest diameter 48 feet 9 inches; its extreme height 95 feet 6 inches; and its cubic contents 122,000 feet. The screw is 29 feet 6 inches in diameter, and the total ascensional force of the balloon 3·799 tons. The rudder for steering the balloon consists of a triangular sail placed beneath it, and near its rear, which is kept in position at the bottom by a horizontal yard 19 feet 18 inches long, turning round a pivot on its forward extremity. The height of this sail is 16 feet 4 inches, and its surface 161 square feet, Two ropes for working the rudder extend forward to the seat of the steerer, who has before him a compass fixed to the car, the central part of which is large enough to carry a crew of fourteen men. The screw is carried by the car, and is driven by four men, or by eight men working at a capstan. The gas-escape valves, of which there are two, are placed at the top of the balloon, immediately over the pendant tubes, and through which the cords for working the valves pass into the car. The conclusions arrived at by M. Dupuy de Lôme, from the results of the trial trip, were,—that the stability of the balloon was perfect, that it manifested no signs of oscillation under the action of the eight men working the screw, and that the shifting of the weight in the car produced no sensible movement. The vertical axis was only shifted, under the most trying conditions, a small part of a degree, and longitudinally there was no change. In comparing the direction of the balloon drifting freely before the wind with the direction given to it when the screw was in operation, it was found that the resultant made with the normal direction an angle of 12°. It is stated, also, that the speed given to the balloon with 27½ revolutions of the screw was 6¼ miles an hour, whilst the rate due to the wind alone was from 26 to 37 miles an hour.

New Railway Projects.—The number of plans deposited at the Private Bill Office of the House of Commons, in connection with new railway projects, amounts to 144. There are also 28 tramway Bills, and 53 Bills of the miscellaneous class, including docks, harbours, local improvements, gas, water, and irrigation works. Amongst the railway schemes there is a proposition to connect the Great Eastern, the North London, and the East London Railways, with the Metropolitan and Metropolitan District Railways. The London and South Western Railway Company propose to effect a junction between their line and that of the London, Chatham, and Dover Company, by means of a railway from their Waterloo Station to the Blackfriars Station of the latter Company. The Metropolitan District Company propose an extension of their line to that of the South Western Company at Barnes. The Metropolitan and St. John's Wood Railway Company propose three new extensions,—to the Hampstead Junction Railway near the Edgeware Road, to join the Midland Railway at the Finchley New Road, and to Green Street, Grosvenor Square, respectively. The Mid-London Railway consists of a series of lines starting from the West end of Oxford Street, and running to the London, Chatham, and Dover Railway near Farringdon Street, and to the East London Railway at St. George's in the East, with junctions to the authorised lines of the Central London and of the East London Railways. Another Mid-London scheme consists in the construction of a railway from the London and North Western line at Willesden to the West end of Oxford Street. Turning to provincial plans, the first proposition of magnitude is the old Brighton, Eastbourne, and London Railway scheme: commencing by a junction with the London, Chatham, and Dover Railway at Penge, and the South Eastern Railway at Beckenham, it runs thence to Brighton and Eastbourne, having branches to Westerham and to the Surrey and Sussex Junction Railway at Oxhead, and a goods branch at Lewes. This scheme involves terms and conditions to be entered into with no less than fifteen existing companies. Most of the main lines have suggestions for extensions in different directions, amongst which we notice one by the London and North Western Railway Company for a line from their Bettws-y-Coed Station to the Festiniog Railway, to be constructed on a gauge of 1 foot 11½ inches, the same as that of the Festiniog Railway. There are four sets of plans deposited for crossing the Severn by bridges, and one for a line to pass under it by a tunnel.

Railway Brakes.—Numerous railway accidents might have been easily prevented had there existed sufficient brake power on the train to enable it to be pulled up more quickly than can be done with brakes on the ordinary system. Naylor's continuous brakes, which have been designed to enable brake power to be applied to each carriage throughout the train, were tried not long since on the Sevenoaks branch of the London, Chatham, and Dover Railway. For a long time it has been feared, in many quarters, that if a set of brakes were applied nearly simultaneously, on a train travelling at a high speed, it might create an unpleasant sensation to the passengers. The above-named trials showed, however, that if the application of the brakes is duly regulated no such effect is produced. Thus, with the experimental train travelling at 57 miles an hour, down an incline of 1 in 101, the driver on the engine applied the set of continuous brakes, shut off his steam, but did not reverse his engine, while his fireman applied the tender brake, yet, even with this suddenly applied retarding force, no unpleasant sensation was experienced by any one in any part of the train. The following are some of the results obtained at the experiments above referred to:—

No.	Gradients.	Speed in Miles per hour.	Distance travelled after applying Brakes and Shutting off Steam.	Time required to pull up.
1	1 in 101 down.	53	Distances not measured.	55 seconds.
2	Do.	43	460 yards.	38 "
3	1 in 101, up not quite all the way, partly down an incline.	35	212 "	20 "
4	1 in 101 down.	57	750 "	60 "
5	Level.	50	700 "	

Mr. Naylor has four different methods of letting his brakes on and of taking them off again. In every case the brakes are let on by slackening out the continuous chain, and the variations in the plans consist in the different methods adopted for tightening this chain, and thus taking the brakes off. Mr. Naylor, in describing the application of his brakes, remarks:—"Everything connected with my brakes is fixed below the under frame of the carriage, and is attached by longitudinal angle irons; between these angle bars two plates are suspended, that carry two pulleys in a fixed position; between these two pulleys there is a third one, which is moved up and down, in connexion with the brake lever, by the continuous chain that runs from carriage to carriage. The force upon the brake lever is obtained by angular links, one attached to the frame, and the other to the end of the brake lever. To the knee joints of these links is applied the tension of the spring. It is obvious that the force pressing upon the brake lever depends upon the strength of the spring, and therefore anything that is required can be accomplished, even to the extent of skidding all the wheels; consequently this brake, when once applied, must be as powerful as any other."

An arrangement for retarding locomotives, by the admission of steam against the pistons, is being introduced by Mr. William Bouch, at the North-Eastern Railway Works at Darlington. A pipe leads from the steam space of the boiler to a longitudinal pipe, which conveys the steam to branch pipes, through which it is admitted into each end of the cylinders at the same time, this steam being admitted after the main supply of steam has been shut off from the ordinary valve boxes of the cylinders, and when it is necessary to retard the progress of the engine or to stop it entirely. The supplementary portion of steam fills both ends of the cylinders, and presses against each of the pistons alternately, so as to act as a cushion in the to-and-fro movement. This mode of retarding the progress of the engine may be used in conjunction with the brakes already fitted to act against the wheels, or it may be used alone, in which case the entire stoppage of the engine would be under the control of the steam cushion.

The Sand Blast.—Tilghman's sand blast has, during the past year, created considerable sensation in the United States. Its object is to drill, cut, or grind, hard substances, such as granite, metal, or glass, and its action depends upon the expulsion, at a considerable velocity, of quartz sand, by a steam or air jet passing through a tube, and striking the material operated upon. In some early experiments made with this apparatus, a hole, 1½ inches in diameter and 1½ inches deep, was drilled through a block of corundum in 25 minutes, with a pressure of steam of 300 lbs. With 100 lbs. pressure a hole, 1 inch by ¼ inch, and ¼ inch thick, was cut through a hard steel file in 10 minutes. At the fair of the American Institute, at New York, last year, a diamond was sensibly reduced in weight in one minute, and a topaz was entirely destroyed. It is a curious feature of this invention that, whilst hard substances are thus rapidly affected, soft and delicate materials are left untouched when exposed to the same influence. Thus, if a thin stencil sheet of india-rubber be laid over a block of granite or marble, and the blast turned upon it, the stone is cut or drilled, while the rubber remains untouched. If a photographic film of bichromatised gelatine be placed on a sheet of glass, and the jet applied, a picture may be engraved, and in the same manner flowers and fern-leaves may be reproduced with the utmost delicacy. For grinding glass a very slight pressure is sufficient, that produced by air under 4 inches of water being ample for the purpose.

ENGINEERING SOCIETIES.

Institution of Civil Engineers.—At the fifty-fourth Annual General Meeting of this Institution it was announced that there were on the books, on the 30th of November last, 14 honorary members, 724 members, 1048 associates, and 203 students,—together 1989, as against 945 ten years ago. At the first meeting in January, Mr. Hawksley, who was elected President at the Annual Meeting, took his seat, and delivered an excellent Address, the leading topics dwelt on being—the use of the Engineering profession to Government in times of war, railway construction, and hydraulic engineering. On the 23rd of January a paper was read on "The Somerset Dock at Malta," by Mr. Charles Andrews. This dock is situated in the French Creek. The works were commenced in 1865, from designs by Col. Clarke, and under the superintendence of Mr. Andrews. The length on the floor is 428 feet; the length over all, 468 feet; the width of the floor, 42 feet 6 inches; the width between the copings, 104 feet; and the width of the entrance, 83 feet. The depth of the invert, floor, and entrance, below the average sea level, is 33 feet 6 inches. The cost of the Dock, inclusive of the caisson, has been about £120,000. The entrance cost £30,000, exclusive of clearing the rock from the site.

An important paper, "On the Value of Water, and its Storage and Distribution in Southern India," was read by Mr. George Gordon, on the 30th of January last. From this paper we learn that there are two general systems employed in India, namely, Tank and Channel Irrigation. The existing tank irrigation is chiefly of native origin, and may be divided into three classes:—1. Tanks formed by the closing of the passage of a considerable river through a narrow gorge, in a range of hills, by means of a high dam or "bund." 2. Those formed in the plains by embankments carried across the drainage of the country, and impounding the water of one or more streams, these tanks being of great superficial area, but shallow. 3. Tanks which might be considered intermediate between the other two, having in general a greater length of dam than the first and a greater depth of water than the second. Few examples of the first kind remain entire. Under the head of Channel Irrigation, it was stated that only rivers of the larger class, which had a continuous flow for several months, were available for extensive irrigation projects. The smaller rivers were merely torrents, which quickly carried off heavy falls of rain and then became dry again. The water, however, is in many cases intercepted by chains of tanks, of the second or third class, built across these torrents. The details of irrigation channels were then dwelt upon, and other particulars,—such as their cost of construction, the net profit per acre upon various crops, loss by evaporation, &c., which it would occupy too much space to follow out in further detail now.

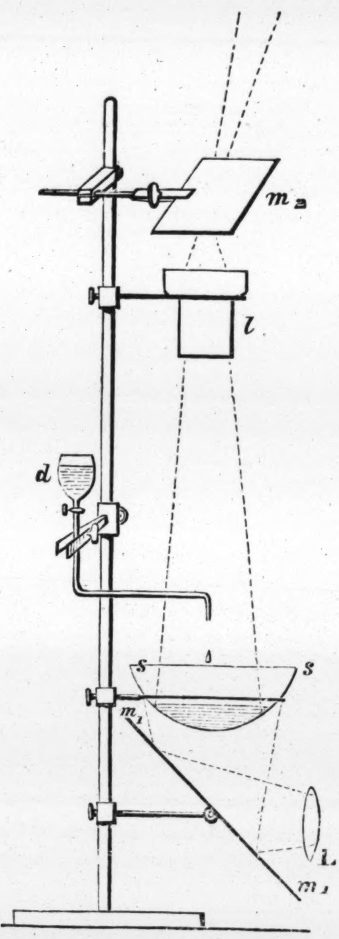
Institution of Mechanical Engineers.—The Members of this Institution met at Birmingham on the 25th of January last. Amongst the papers then read were two to which we shall here refer, viz., "On the Strength and Proportions of Rivetted Joints," by Mr. Walker Brown, of Bristol, and "A Description of the Disintegrating Flour Mill, and Machine for Pulverising Minerals, &c., without Grinding, Crushing, or Stamping," by Mr. Thomas Carr, of Bristol. In the former paper, four different modes of fracture possible in rivetted joints were described, consisting in—shearing of the rivet; crippling of the plate, or elongation of the rivet hole in the line of strain; fracture of the metal between the rivet hole and the edge of the plate in the line of strain; or tearing of the plate along the line of the rivet holes, at right angles to the line of strain. From the consideration that a perfect joint would be one offering equal resistance to each of these modes of fracture, the proper proportions were deduced for the various descriptions of rivetted joints, with the aid of data furnished by different experiments previously recorded, and by a series of experiments recently made for the purpose by the writer.

In the process of disintegration by Carr's Disintegrator, the particles of the material operated upon are shattered in mid-air by a succession of blows delivered with extreme rapidity in opposite directions, and are thus pulverised by the force of the blows alone, without being subjected to the compression or friction which accompanies the ordinary processes of grinding, crushing, or stamping the material between two surfaces. The disintegrator consists of a pair of circular discs, rotating in contrary directions upon two shafts situated in the same line; the opposing faces of the discs are studded with a series of short projecting bars, or beaters, arranged in successive concentric rings or cages; and the rings of beaters fixed in one disc intervene alternately between those fixed in the other disc, and revolve in the opposite direction. The material to be pulverised is supplied through an opening in the centre of one of the discs, and receives from the innermost rings of beaters a centrifugal motion, propelling it towards the circumference of the discs: in its course through the machine it encounters successively the several rings of beaters revolving alternately in opposite directions at a high speed, and the particles are thus dashed violently by each beater against the beaters in the next outer ring running in the contrary direction, whereby the material is effectually broken up and reduced to powder.

MECHANICS.

At the Meeting of the Royal Scottish Society of Arts on the 11th of March, an apparatus was exhibited by Dr. R. M. Ferguson, for showing the motion of waves on the surface of a liquid, and for illustrating more particularly the propagation, reflection, and interference of the waves of sound. It is similar in principle to that exhibited by Professor Morton, in Philadelphia, and described in our last October number. It has the advantage, however, of greater simplicity, and is merely a combination on an ordinary chemical stand of things generally in the hands of a teacher of science, and used for the most part for other purposes. The accompanying cut shows the arrangement. *l* is the illuminating lens of a magic lantern. *m* is a plate-glass mirror placed at 45° to turn the horizontal light into a vertical direction; *ss* is a glass saucer made by cutting the end from an ordinary glass shade; *l* a photographic lens; m_2 a second mirror to turn the light again horizontal but at right angles to its first horizontal direction upon a screen. The glass dish is partially filled with methylated spirits, and the dropping apparatus, *d*, intended to excite the waves, is filled with the same liquid. This last consists of a Wolff's bottle funnel, furnished with a glass stopcock (of the ordinary German make), bent into the form shown, and having its lower extremity where the drop issues drawn out into a pipette point. The whole can be fitted to a retort stand with the aid of the usual rings and clamps that form the complement of its "fixings." The great difficulty in making a successful arrangement for exhibiting what must necessarily lie horizontal on a vertical screen, is the full illumination of the object to be exhibited. The diverging cone of rays that falls on the surface of the liquid is in no way altered in its divergence when it passes through a flat transparent vessel. The surface of the liquid is perfectly transparent and does not catch the light. The cone of rays therefore continuing to expand as it approaches the defining lens *l*, passes for the most part outside of it, and hence the imperfect illumination. The glass shade and its liquid contents form a converging lens, which throws the whole light incident on it through the lens *l*, and thus no light is lost. The course of the light is shown by the dotted lines. In Professor Morton's apparatus, a horizontal lens is placed immediately under the flat-bottomed vessel containing the liquid to effect the necessary convergence. In Dr. Ferguson's arrangement the lens and containing vessel are one and the same thing. Such composite lenses were stated to be singularly accurate and effective, and give considerable latitude in regard to size. The glass dish used was 8 inches in diameter, and was filled to form a lens 6 inches in diameter. It was cut from a shade whose cylindrical part was 10 inches across. The surface of the liquid was in focus with the lens used at about 9 inches, but the waves were best seen when the lens was 15 inches distant. The dropping apparatus can be brought over any part of the surface, and the rapidity of the drop regulated by the stopcock. When the glass dish is full, different figures with upright sides of metal plate can be placed in it so as to alter the shape of vessel at will, and illustrate the conformation of the wave systems of plane figures of all kinds. The sides of these reflect the waves, and the outer edges can be darkened with paper so that only the inside is seen. The waves were exhibited by the aid of the lime-light, on a screen 15 feet in diameter, with singular beauty and clearness. The same apparatus was used to illustrate a course of lectures on Sound, in the Edinburgh Museum of Science and Art. The screen employed in this case was a square sheet of ground glass, 3 feet in size, when the demonstrations could be distinctly seen by the audience in the full blaze of the gas of a hall well lit by sunlights. Spirits were used instead of water, as under the conditions they give a slower wave and a clearer definition.

FIG. 22.



Lockwood and Co. will publish on April 1st the first number of a new Quarterly, under the title of "Naval Science," a magazine intended to promote the improvement of Naval Architecture, Marine Engineering, Steam Navigation, and Seamanship. Its appearance is looked for with considerable interest in naval and scientific circles, as it is to be edited by E. J. Reed, C.B., late Chief Constructor of the Navy, and the contributors will include the most eminent authorities in the several branches of the above subjects.

LIGHT.

In the oxyhydrogen light the use of cylinders of burnt dolomite in place of ordinary lime is recommended as increasing the regularity of the light.

An interesting observation upon the influence which the temperature of the prism exercises upon the position of the lines has been made by M. Blaserna. It has already been noticed by Verdet, that where liquids are used for prisms, the displacement of the lines is quite noticeable, the index of refraction altering with the temperature. For solid prisms, however, it was assumed that the influence of change of temperature upon their refractive power was quite insignificant. M. Blaserna has found, however, upon observation, that this is not so unimportant as is generally believed; but that, while much less sensitive than liquid prisms, the displacement of lines could readily be observed with one of flint glass. The prism used in the experiment was one of Duboscq's, and was exposed for some time to the direct rays of the sun. It was then quickly placed in a spectroscope in the shade and some prominent line observed, when it was found that as the glass cooled the refractive power increased. (An opposite result is obtained for bisulphide of carbon). He was able to observe in this manner a displacement of the D line, amounting to 3″ for a difference of temperature equal to 1° C. In the instrument used the interval between D and D′ is 12″, so that a change of 4° C. would suffice to place D in the position of D′. M. Blaserna remarks, as the result of his interesting observation, that an error might very readily be made in spectroscopic work, by comparing together observations made in sunlight and in shade, or those made in the morning with those in the night.

In "Poggendorff's Annalen," M. L. Schonn contributes a paper on the employment of cylindrical lenses in spectroscopic observations. As in observations of the spectrum we have to do with lines of light, and these, moreover, straight ones; and as, in addition, it is not necessary that the rays falling on the prisms should all be parallel to each other, but only that they should all be in parallel planes, M. Schonn thinks it would be far better to make use of lenses suited to this especial purpose, and to employ throughout none but cylindrical lenses also for illuminating the slit. From a preliminary examination he has ascertained that one thus obtains well-defined spectra, in which the full extent of the prism is rendered available. Perhaps, also, another disposition of the spectrum might at the same time be recommended—namely, one wherein the image of the slit should be horizontal, inasmuch as lines that lie in a horizontal position are seen with greater precision.

Just before going to press we received, through the Royal Astronomical Society, an announcement of the discovery of a minor planet (118), Peitho, at Bilk, by Dr. R. Luther.

	M.T. at Bilk.										
1872.	h.	m.	s.		h.	m.	s.		°	′	″
March 15	14	18	59·6	R.A. =	12	7	26·73	N.P.D. =	79	42	33·5

From an observation made by Dr. Tietjen, at Berlin:—

	M.T. at Berlin.										
1872.	h.	m.	s.		h.	m.	s.		°	′	″
March 21	9	33	23	R.A. =	12	1	36·36	N.P.D. =	79	20	46·1

The daily motion obtained from these observations is in R.A. – 60·6″, and in N.P.D.—3′ 45″. The planet is of the 11th magnitude.

Microscopy.—An improved erector for use with binocular microscopes has been contrived by R. H. Ward, M.A., M.D., Professor of Botany and Microscopy in Rensselaer Polytechnic Institute, U.S. The lenses of a 1½ or 2-inch objective may be packed or screwed into the upper end of an adapter, which when screwed into the nose-piece of the microscope, carries them up close to the binocular prism, and into the lower end of which the object-glass may be screwed. A more convenient arrangement is an adapter with a sliding tube adjustment, which varies to the extent of an inch or more the distance between the erector and objective. Different powers and distances will of course be used according to the wants of different observers. The combination considered most convenient by the inventor consists of a 2-inch erecting lens close to the binocular prism, and a ⅔-inch objective at a distance measured to its lower end of from 3 to 4½ inches below the erector, giving powers of from 10 to 50 diameters, and requiring a working distance between the stage and the binocular prism of 4½ to 5 inches, which is quite practicable with large stands. Where sufficient working distance cannot be obtained, the object may be placed upon the sub-stage, or more conveniently, the sub-stage removed, and the body racked down, so as to focus through the empty stage upon the table, where the object may be supported by any convenient method. A modification of the above has been arranged by Mr. F. Oxley, of the Quekett Microscopical Club. Into the nose-piece of the microscope he screws a 3-inch or 4-inch objective, and has a sliding fitting made with the universal screw to carry an objective placed beneath the stage. The object to be viewed is placed on the table, where it can be very conveniently manipulated; a 1½-inch objective beneath the stage answers very well in combination with a 4-inch (the single combination of Ross) on the microscope. This arrangement has the advantage of being inexpensive; it can be adapted to any microscope at a cost of a few shillings. This erector is free from many of the objections to the usual erector placed within the body. The view given of the object is extremely good, and considerable variation of magnifying power may be obtained by altering the distance between the two objectives. The microscope is really converted into a telescope of short focus, the inverted image being formed by the combination below the stage, and again inverted and consequently erected by being viewed with the binocular microscope. The contrivance is especially valuable to those who have dissections or other manipulations to conduct under the microscope: all such operations can be carried on in the most comfortable manner, with the hands resting on the table, and the body free from the constrained stooping position involved in the use of single microscopes; and all these advantages combined with the large field, fine definition, and capability of distinguishing vertical distances which are so peculiarly the properties of a good binocular instrument.

"Silliman's Journal" contains an account of a new eye-piece micrometer and goniometer, designed by Dr. H. T. Porter and Mr. J. P. Southworth. The scales in both instruments are made by photography instead of the usual process of engraving with a ruling machine and diamond. The original scale being drawn upon paper and consisting of 100 heavy black lines about ⅛th of an inch apart, the lines marking every ten divisions are 6 inches long, and extend 1 inch on each side of the scale; those marking each five divisions are 5 inches long and extend half an inch on each side; the remaining lines are 4 inches long. A negative is taken in which the scale is reduced to 2 inches in length. From this a transparent positive is taken reducing the scale to about half an inch in length. In this the lines are $\frac{1}{200}$th of an inch apart. A thin glass cover is cemented on with Canada balsam for the protection of the lines; it is then mounted in a similar manner to Jackson's micrometer. For the goniometer, a circle about 18 inches in diameter is drawn with India ink, and divided into degrees. The centre is indicated by a dot, and one diameter is drawn. Every five and ten degrees are indicated by longer lines than those indicating single degrees; every ten degrees of each quadrant are numbered from 0° to 90°. A negative of this diagram is taken as before, and a reduced positive of a size to fit the tube of the microscope; this disc is mounted to fit the tube at the focal point of a positive eye-piece. A cobweb is drawn across the diameter of the lower lens. When a crystal is to be measured, the stage is moved until the apex of the angle coincides with the centre of the goniometer, and the diameter with one side. The eye-piece is now turned till the cobweb crossing the diameter at the centre coincides with the other side of the angle. The number of degrees can be read off at the circumference without the trouble of looking outside as in ordinary contrivances or reading the verniers of a rotating stage. The inventors claim for these photographic scales the advantages of cheapness and greater legibility than that of the usual ruled ones. The transparent spaces are quite clear enough not to seriously impair the definition of the instrument.

In the course of some remarks on the structure of the Arborescent Lycopodiaceæ of the Coal Measures, delivered before the Royal Microscopical Society, by Mr. W. Carruthers, F.R.S, it was mentioned that the late W. Nicol of Edinburgh, well known as the inventor of the single image prism, was the discoverer of the mode now in use of making sections of fossils for microscopical examination. His large collection is now deposited in the British Museum.

A good substitute for a cement which is a favourite with many microscopists, although far from trustworthy, viz. asphalte, will be found in a varnish employed by Messrs. Horne and Thornthwaite in the process of etching thermometer tubes and other glass instruments. Ordinary varnishes were found to fail for this purpose, as they permitted the hydrofluoric acid to creep under the ground and so cause a rough imperfect line to be etched; the new varnish resists the acid perfectly. Its good qualities for the microscopist are—that it adheres well to glass, and when hard does not become brittle, but comes away in shreds when scraped, like gold size, the most reliable of varnishes for fluid mounting; its advantage over gold size is that it possesses more body, owing to an admixture of a suitable quantity of copal. This property renders it very suitable for making cells on the turntable; these are, however, much improved by baking at a moderate temperature, like japanned wares, without which process all cells formed of oil varnish are liable to be softened by subsequent coatings: neglect of this precaution is a frequent cause of objects mounted in such cells being spoiled by the running in of the cement.

HEAT.

M. Laborde has made some experiments on calefaction. He let a thin thread of water pass through the jet from the blowpipe, and he found on examination that the water which had thus passed through a heat capable of melting almost any metal was but slightly warmed; in fact, the difference was but 3°. If a jet is passed through an ordinary flame the increase in temperature is considerably higher, probably owing to the incandescent particles carried away by the liquid from the smoke. A sheet of water presents similar evidence. If the jet from the blowpipe is directed against it it is not pierced, nor is there any sensible heating effect; the finger can be brought to within a few millimetres of the flame, and yet there is no sensation to indicate the near proximity of an otherwise so potent source of heat.

"The event of the *séance*," says the Abbé Moigno, in "Les Mondes," speaking of a recent meeting of the Academy of Sciences at Paris, "was a truly singular and noteworthy incident connected with the subject of the sun's temperature. On the one hand, Father Secchi maintained, and attempted to establish, his figure of ten million degrees of temperature (centigrade) against MM. Ericsson, Zöllner, and Faye; on the other hand, M. Vaulle, Professor of the School of Mines, and formerly a Laplace prizeman, established by means of a very learned and novel theory, a maximum temperature of 10,000 degrees. Thereupon, M. Henry Sainte-Claire Deville announced that he is engaged in determining the temperature and pressure at the sun's surface, and asserted (as the result of his first researches) that the sun's temperature exceeds some three or four times the temperature at which platinum melts, amounting, therefore, to from 6000 to 8000 degrees. Next, M. Fizeau stated, that having compared (like M. Leon Foucault) the solar light with that of the glowing carbon points of the electric light, he had estimated that the former is about three times as intense as the latter; hence, inferring the relative calorific intensities from the observed relative luminosities, he also had deduced a solar temperature of 8000 degrees. So that, according to French science, the solar heat does not exceed 10,000 degrees; and, in fact, it is emitted by ignited and dissociated terrestrial elements.

MM. E. and M. Becquerel have made some observations on the differences of temperature at divers depths between turfed and denuded soil, when both were covered with snow. They were made in the Jardin des Plantes, Paris, two contiguous pieces of ground being chosen for the purpose, one of which was covered with short vegetation, the other being bare. The thermo-electric pile was used to detect the differences of temperature. Snow commenced to fall at Paris about two o'clock in the afternoon on the 7th of last December;

the next day the earth was covered with a layer having a mean thickness of between 7 and 8 centimetres. The temperature of the air rapidly fell on the 9th, the minimum observed at the Jardin des Plantes was 20·7° C., and at the Observatoire 21·5° C. The table of observations of the temperatures observed at different depths beneath the snow-covered soil, show, however, that at no time was it lower than the zero of the centigrade scale in the case of the turfed ground, at depths of 0·05 m. and 0·03 m. At the depth of 0·05 m., the temperature, starting about 0·05° C., rose to 0·7° C.; at 0·1 m. and 0·3 m. the temperatures were 1 and 2 degrees, and the variations 1 and $\frac{2}{10}$ths of a degree, indicating a tolerably constant temperature at each station. At these depths, therefore, in ground of this kind, roots, seeds, and other organic bodies are preserved from the ill effects of a frost even of 20° below zero. In the case of denuded soil, it was otherwise from the 2nd of December to the 6th, at a depth of 0·05 m.; the temperature was always below zero, and on the 15th at zero. On the 7th it was 1°, after which it continued to fall till the 10th, from which it again rose a few tenths daily up to the 15th. From the preceding observations, it therefore appears, that a bed of snow 7 or 8 centimetres in thickness, completely protects objects at a depth of 0·05 m. from even such a severe frost as 20° C., if the earth is turfed; whilst when it is bare, the temperature at the same depth is 1·5° below zero. Seeds and roots will therefore be kept with perfect security in turfed ground, which, if the ground had been ploughed or otherwise tilled, would undoubtedly have perished.

MM. Leygue and Champion have invented an apparatus for measuring the temperature of the detonation of explosive compounds. The apparatus is founded on the known distribution of the temperature in a metallic bar heated at one of its extremities, and consists simply of a copper bar of 0·025 m. diameter and of 0·60 m. length. Small cavities are drilled in the bar at distances 0·10 m., these cavities being filled with oil in which the bulbs of small thermometers are immersed. The following are some of the temperatures of the detonation of the chief explosive compounds; the degrees are centigrade. Chassepot powder, 191°; fulminating mercury, 200°; Abel's protoxide, 205°; sporting powder, 288°; picrate of potash, 336°; nitro-glycerine, 256° to 257°; artillery powder, 380°.

M. Fosselli has succeeded in producing an amount of cold just below the zero of the Fahrenheit scale by simple mechanical action, creating rapid evaporation. He employs a wheel formed of a spiral tube, both ends of which are open, set vertically and half immersed in the fluid to be cooled, so that the latter passes constantly through the whole length of the tube, half of which is constantly above the liquid, and being wet, gives rise to active evaporation and consequent refrigeration within it.

M. Ch. Tellier describes an arrangement and apparatus whereby the vapourisation of ether is employed for the production of intense cold, provision being made to recover the ether in a very ingenious way, by causing it to be absorbed by sulphovinic acid, from which it is afterwards again separated by a simple distillation. An apparatus is now being made according to the author's instructions with which it will be possible to manufacture a ton of solid ice per hour, while the apparatus, of great simplicity and without any complicated fittings, will admit of constant action, and thereby making the ice at a very low price.

Mr. Fletcher has brought out an improved gas furnace and hot-blast blowpipe. The speciality of this furnace is the burner. It is as simple as an ordinary Bunsen's burner, but the flame is solid to the centre. Copper will fuse in any part of the flame; and to make a crucible furnace simply requires a support for the crucible, and a fire-clay jacket to prevent radiation. The lower part is a chamber 6 in. by 3 in., open at the bottom, in which the gas is partially mixed with air. This mixture is conducted to the top of the burner through a mass of fine tubes, with an arrangement to supply between each exactly the amount of air necessary to consume it instantly. A flame produced by this means, consuming 20 feet of gas per hour, is about 2 inches high and almost colourless. The whole of the available heat is generated below the object to be heated, which, therefore, is not also cooled by the passage of unburnt gas and air. The point of greatest heat commences, as with a blowpipe, at the point of the blue cones, about ½ in. or ¾ in. above the tubes; and if the flame is protected with a ring of fire-clay, continues uniform for some inches above. The great heating power of the hot-blast blowpipe is obtained by an arrangement which enables both gas and air to be supplied to the jet at an exceedingly high temperature. The jet will fuse a strand of 6 or 8 fine platina wires into a bead with a small point of flame, and will give a small light with a cylinder of lime. With the gas fully turned on, it will melt 3 ozs. of 18-carat gold on pumice-stone. Steel wire burns readily, with brilliant scintillations, and wrought-iron wire is readily fused. The additional heating power may be used or not at will, and the blowpipe can be used either with the mouth or a foot-blower; when used with the mouth the head is not confined in one position, as in case of the old form, and both hands are at liberty. The extreme power is exerted to the best advantage on as small objects as possible, and when the gas is turned down to a blue cone of about 1 or 1½ inches long. The point of this blue cone will fuse a few grains of platinum, supported on lime, in five or six seconds, if a foot-blower is used. If, however, a smaller quantity is taken—say half a grain—it is fused into a bead instantly, either with the mouth or a foot-blower. If a platinum wire is used, it should be held with the point exactly in front of the point of the blue cone. With care, a bead may be fused on the end of a platinum wire almost as thick as ordinary copper bell wire. If a very fine wire is used, it will melt almost as quickly as it can be passed along the flame: in these experiments the eyes should be protected from the blinding glare of light, more especially in fusions on lime. For soldering and heating platinum crucibles, the gas should be turned full on, so as to produce a large rough flame, the heating power of which is about double that of the ordinary blowpipe. The lower burners need never be turned on more than is necessary to allow the flame just to reach the top of the coil.

ELECTRICITY.

The electric currents obtained by the bending of metals have been examined by P. Volpicelli. After relating at length his method of experimenting, he summarises the results of his experiments in the following points:—All metals when being bent or twisted give rise to the development of an electric current, but copper exhibits this phenomenon in the highest degree. Lead, although not an elastic metal, also gives rise to the generation of an electric current, thus exhibiting an instance of the conversion of mechanical force into electricity; the electric currents thus produced are not perceptibly due to the development of heat due to the action of bending or twisting. When the bending is accompanied by the tearing asunder, or, rather, the distending, of the two ends of the metallic wire, a current is produced in an opposite direction from that obtained by putting the two ends nearer together; by increasing or decreasing the velocity of the bending, the intensity of the electric current is also increased or decreased. A metallic wire made of various metals soldered together produces, other conditions being the same, a less intense current by bending than when the wire is made of one and the same metal.

M. Eugenio de Zuccator has invented a novel method of rapidly copying manuscripts or designs, whether produced by hand or photography. An ordinary letter copying press is used for printing from the design, which is formed upon a varnished metal plate. This plate, which is of iron, is either coated with a shellac varnish, and the writing or design to be copied then traced thereon with a metal point, or it may be coated with gelatine and bichromate, and the design produced by means of photography with a transparent positive. In any case the lines are formed of bare metal upon a surface of varnish. One wire of an electric battery is connected to the bed of the copying press, and the other to the upper plate of the instrument, so that when the press is screwed down and the top and bottom plates come in contact, an electric current passes. The varnished metal plate, upon which a memorandum has been scratched, or otherwise produced, is covered with a few sheets of copying paper wetted with an acid solution of prussiate of potash, and then screwed into the press. The characters or design upon the varnished plate are formed of bare metal, and in these parts an electric current is set up; this action permits of the union of the iron with the potash, and the consequence is, Prussian blue is formed in lines corresponding to those upon the varnished plate. Copies thus produced in blue ink may be printed at the rate of 100 per hour. The patent is the property of Messrs. Waterlow and Sons.

At a recent meeting of the Royal Society, a paper was read by Professor J. Clerk Maxwell, F.R.S., "On the Induction of Electric Currents in an Infinite Plane Conducting Sheet." The paper contained a scientific demonstration of what takes place in a conductor of infinite extent, acted upon by a system of magnets or electro-magnets. It is of singular importance in giving an insight into the action of dampers on magnetic needles, such as Harris's copper ring surrounding a ship's compass; in fact, into those causes which check the vibration of needles, and which seem to exercise a kind of unseen friction on suspended magnets. The author states that former writers do not take into account the inductive action of the currents on each other, though the existence of such an action was recognised. In his investigation a system of magnets or electro-magnets is supposed to exist on the positive side of the sheet; and to vary in every way by changing its position or its intensity. The nature of the currents induced in the sheet, and their magnetic effect at any point, and in particular their reaction on the electro-magnetic system which gave rise to them, are determined. The result is presented in a simple form by the aid of the principle of images which was first applied to problems in electricity and hydrokinetics by Sir W. Thomson. The essential part of this principle is that we conceive the state of things on the positive side of a certain closed or infinite surface (which is really caused by actions having their seat on the surface) to be due to an imaginary system on the negative side of the surface, which, if it existed, and if the action on the surface were abolished, would give rise to the actual state of things in the space on the positive side of the surface. The state of things on the positive side of the surface is expressed by a mathematical function which is different in form from that which expresses the state of things on the negative side, but which is identical with that which would be due to the existence, on the negative side, of a certain system which is called the image. The image, therefore, is what we should arrive at by producing (stretching), as it were, the mathematical function, as far as it will go; just as in optics the virtual image is found by producing the rays, in straight lines, backward from the place where their direction has been altered by reflection or refraction. In the case of a plane conducting-sheet there is a moving train of images. If positive and negative images, according to the sides of the plane, are formed and started at given intervals of time, a train or trail will begin with a single positive image, followed by an endless succession of pairs of images. This trail when once formed continues unchangeable in form and intensity, and moves as a whole away from the conducting-sheet with a constant velocity. If the conductivity of the sheet were infinite, or its resistance zero, that velocity would be zero. The images, once formed, would remain stationary, and all except the last formed positive image would be neutralised. Hence the trail would be reduced to a single positive image, and the sheet would exert a repulsive force on the pole, whether the pole be in motion or at rest. This case does not occur in nature as we know it. Something of the kind is supposed to exist in the interior of molecules in Weber's theory of diamagnetism.

With the first day of this year the electric light was introduced at the South Foreland Lighthouse, which is situated between Dover and Deal. The position is of great value owing to its situation with regard to the opposite coast of France and the approaches to the North Sea and the mouth of the Thames. The completion of the works at the Foreland will form a triangle of electric lights described by those of Dungeness, Cape Griznez, and the South Foreland. The South Foreland towers are 449 yards apart, and their lights are respectively 372 feet and 275 feet above high water of spring tides. Buildings for the requisite machinery and apparatus for the production of the electric light have been erected midway between the two lighthouses. The electricity is generated by one of Professor Holmes's magneto-electric machines, worked by a small horizontal condensing engine. There are four of these engines, two being for the service of each lighthouse—one used ordinarily, but in times of fog both. They make 400 revolutions per minute, effecting with this speed an alternation in the direction of the currents of 6400 times in the same period. The electrical currents are sent from the machines by underground wires to the lantern of each lighthouse. The steam-engine, boiler, and magneto-electric machines are all duplicated in case of accident or want of repair to any part. The supply of water for the steam-engines is obtained from a well sunk through the chalk a depth of 280 feet to the high water level of the sea. This well, although the water is remarkably pure and free from salt, is curiously affected by the action of the tide. During each flood-tide, the well is quite dry, but throughout each ebb-tide there is an abundant supply of water. The optical apparatus in each lantern is of the dimensions of a third order for fixed light, but has been especially designed and manufactured for the purpose of the electric light. From the high lighthouse 246 degrees of the arc surface is illuminated, and from the low lighthouse the arc illuminated is 106 degrees. The landward arc of the light, instead of being waste light to the mariner, is also utilised, and is in each case carefully gathered up, and by reflecting prisms arranged on each side of the main apparatus, equally distributed over the portion of the surface illuminated by the latter, thus adding very considerably to the power. Each apparatus is provided with an efficient oil-lamp as a further precaution in case of accident.

M. Trouvé has found a new application of electricity to medical purposes in his electric probe for bullet wounds. This probe consists of three distinct parts, the battery, the probe, and the indicator; and the adaptation is founded on the conductibility of metals. The battery is an ordinary zinc-carbon element, the exciting liquid being bisulphide of mercury. The probe is flexible or rigid, and is a conductor. The indicator has in its interior a very small electro-magnet with a vibrator and two small rods of steel, very sharp and insulated from each other; and as soon as these points, which are in connection with the battery, touch any metallic substance, the vibrator begins to move. The surgeon with this apparatus can even distinguish the different metals from one another. If the metal is lead, the trembler vibrates regularly; if, however, it is iron or copper, the trembler has a jerky movement. Iron may be distinguished from copper by its action upon the needle of a galvanometer.

Dr. Joule has given a note of some experiments on the polarisation by frictional electricity of platina plates, either immersed in water or in alternate series with wet silk. The charge was only diminished one-half after an interval of an hour-and-a-quarter. It was ascertained both in quality and quantity by transmitting it through a delicate galvanometer. He suggested that a condenser on this principle might be useful for the observation of atmospheric electricity.

Some investigations of a novel kind relating to the directive power of large steel magnets, bars of magnetised soft iron, and of galvanic coils in their action on external small magnets, have been brought forward by Dr. Airey, C.B., P.R.S., Astronomer Royal, and James Stuart, M.A. The experiments show the distribution of force in the sphere of magnets, and a marked difference was observed between the behaviour of an ordinary steel magnet and that of a galvanic coil without a core; for whereas in the instance of the steel magnet the focus lies within, and some distance from, the end of the bar, the focus of the coil was found to be at the centre of the end of the coil. It would be interesting to know if this be so, for it might be supposed that the focus is a little distant from the flush end, perhaps little more than one-twelfth part of the diameter of the coil's wire from it. The presumption would be that the rings of the coil have, unless clasping a core, each a magnetic action of their own, besides their combined action, and that it is the last ring which determines the focus alluded to. The apparatus used for the experiments is a bar magnet, 14 inches in length, placed, in one series, with its edge towards the small compass on which its directive power is estimated, and another series with its flat side towards the small compass; also a galvanic coil, 13·4 inches in length, animated by a battery of three cells, and in the same coil, with the insertion of a soft iron coil. In the field of experiment the earth's magnetism was sensibly neutralised by external large magnets. The observations with the small compass were taken in thirty marked stations in one oval ring surrounding the magnet, and in thirty-eight stations of another oval ring outside the first one. The following specific points are remarked:—At a constant distance from the steel the greatest force exerted by a *magnet* is not the longitudinal force at the end, but the transverse force near the end. In going round the magnet there are six maxima and six minima of force. The law of attraction of the *core* of a galvanic coil is not very different from that of a magnet. The force produced by the core within the coil is very much greater than that produced by the coil alone. In some positions of the small compass it is about forty times as great, and in some about *one hundred and seventy* times as great. The law of force at different parts of the *coil* differs greatly from that at corresponding parts of the magnet or core. In the coil it is proportionally far greater at the end, and its direction is different. Near the end of the magnet or core the directions of force converge to a point within it distant from the end by about one-twelfth of its length. Near the end of the coil the directions of force converge to a point as exactly as possible at the centre of the end of the coil.

M. Becquerel, in a paper "On the Chemical Effects of Caloric in the Action of Powerful Electric Discharges," states that the reduction of oxides of silver, lead, tin, and copper, can be effected by mixing these substances with charcoal dust in U-shaped tubes, and exposing them to the heat derived from the discharge of a powerful induction apparatus; the oxides of nickel, cobalt, iron, and chromium, mixed with charcoal powder and powdered sugar, and put in a platinum crucible, are also reduced. Silica and alum are fused, and small crystals are sometimes found in the fused mass.

In spite of the labours of Faraday and of L. Foucault, and in spite of the excellent arguments of these two great physicists in favour of the conductibility of liquids without electrolysis, this conductibility is not generally admitted. M. Favre has endeavoured to elucidate the subject, and has sought to show that, under some circumstances, the electrolysis of a liquid traversed by an electric current is impossible. He placed in circuit with a single Daniell's cell an electrolytic cell of sulphate of copper: after a quarter of an hour there was a deposit of copper in the pile, but on the negative plate of the voltameter there was found neither the metal nor its oxide. On the porous cup of the element there was also copper deposited. With the voltameter out of circuit and the circuit of the element open, copper was deposited on the porous cup only. And by several carefully considered experiments M. Favre shows that the volume of gas disengaged in the voltameter is by no means equivalent to the reduction and oxidation of the materials of the pile, thus proving that a portion of the current must have traversed the liquid without electrolytic effect. He finds, also, that three Smee's cells are needed to decompose sulphuric acid; it requires, it would seem, a force corresponding to 45,000 calories in order to electrolyse the acid.

Sir W. Thomson gives the following law for rendering galvanometers sensitive with a minimum of wire. The curve forming the transverse section of the coil is expressed by—

$$x^2 = \left(\frac{y}{a}\right)^{\frac{2}{3}} - y^2,$$

x being the abscissæ from the zero point, passing through the magnet; y, the ordinates; and a, a constant.

Prof. Osborne Reynolds, from some experiments on the electro-dynamic effect the induction of statical electricity causes in a moving body, has been led to the consideration of the induction of the sun as a probable cause of terrestrial magnetism. If an electrified body be placed near a moving conductor so as to induce an opposite charge in the moving body, this charge will move on the surface of the conductor so as to remain opposite the electrified body, whatever the motion might be. Suppose the moving conductor to be an endless metal band running past a body negatively charged, the positive charge would be on the surface of the band opposite to the negative body; and here it would remain, whatever might be the velocity of the band. The effect of the motion of this negative electricity on the conductor would be the same as that of an electric current in the opposite direction to the motion of the band. If the moving body consisted of a steel or iron top spinning near the charged body, the effect of the electricity on the top would be the same as that of a current round it in the opposite direction to that in which it was spinning. It might be that the electricity in the inducing body would produce an opposite magnetic effect on the top; but even if this were so, its effect, owing to its distance, would be much less than that of the electricity on the very surface of the top. If no account were taken of the effect of the inducing body, the current round the top would be of such strength that it would carry all the electricity induced in the top once round every revolution. If the top were spinning from west to east by south it would be rendered magnetic with the positive pole uppermost, that is, the pole corresponding to the north pole in the earth or the south pole of the needle. In one of the experiments, to show that such a current might be produced, a glass cylinder, 12 inches long and 4 inches across, was covered with strips of tin-foil, parallel to the axis, with very small intervals between them. These strips were about 6 inches long and ½ an inch wide, and the intervals between them $\frac{1}{200}$th of an inch. In one place there was a wider interval, and from the strips adjacent to this wires were connected, by means of a commutator, with the wires of a very delicate galvanometer. This cylinder was mounted so that it could be turned 1200 revolutions in a minute, and brought near the conductor of an electrical machine. This apparatus, after it had been thoroughly tested, was found to give very decided results. As much as 200° deflection was obtained in the needle, and the direction of this deflection depended on the direction in which the cylinder was turned, and on the nature of the charge in the conductor. When this was negative, the current was in the opposite direction to that of rotation. It may be taken as experimental proof of the fact previously stated, that, if a steel top were spinning under the inductive influence of a body charged with negative electricity, the effect would be that of a current round the top such as would render it magnetic. The cause of terrestrial magnetism has not been the subject for so much speculation as many other more unimportant phenomena, being regarded as a cause from which other phenomena might result, but not, as itself, the result of other causes, and yet when two phenomena have a relation to each other there is good reason for believing them connected in some way, either one being derived from the other, or else both springing from the same cause. The direction of the earth's magnetism bears a marked relation to the earth's figure, and yet it can have had no hand in giving the earth its shape, which is explained as the result of other causes. Assuming that the figure of the earth has something to do with its magnetism, its rotation, which keeps it in shape, causes it to be magnetic. We are led to believe the cause of this magnetism to be associated with the sun, from the influence it exerts on this magnetism, although the cause itself cannot be the result of either the sun's heat, light, or attraction. The analogy between the magnetism produced by a spinning top by the inductive action of a distant body charged with electricity, and the magnetism in the rotating earth, probably caused by the influence of the sun, which influence is not its *mass* or heat, seems to suggest what its influence really is. If the sun were charged with negative electricity, it seems to follow, from Prof. Reynolds's experiments, that the inductive effect upon the earth would be to render it magnetic, the poles being as they are.

TECHNOLOGY.

Ordinary brick-dust, made from hard-burnt, finely pulverised bricks, and mixed with common lime and sand, is universally and successfully employed as a substitute for hydraulic cement in the Spanish American dominions. It is regularly known in Cuba as an article of commerce, and sold in barrels, by all dealers in such articles, at the same price as cement. The proportions used in general practice are one of brick-dust and one of lime to two of sand, mixed together dry, and tempered with water in the usual way.

For curiosity's sake we quote the following account of a series of experiments made on January 27th last at Fort de Montrouge, in the presence of His Majesty Don Pedro II., Emperor of Brazil, for the purpose of testing dynamite:—"An iron-hooped, well-made, oaken cask, of 2 hectolitres (rather more than 44 gallons) cubic capacity, was placed in a vertical position, then filled with water, and a square hole left in the lid, the size of the hole being sufficient to admit of throwing through it a parcel of four cartridges, each containing 20 grms. of dynamite, care being taken to light the fuses previous to casting the cartridges into the water. After the explosion not a trace even of the cask was to be seen, and on the spot where it had been standing a funnel-shaped hole was formed, 4 decimetres (15·748 inches) deep."

According to Dr. Sézille's new process of panification, which is spoken very highly of on the Continent, the wheat is first deprived of its outer cover, or husk, by means of properly constructed machinery; the decorticated grain is next acted upon several times by tepid water (about 80° for the first bath and 40° for the subsequent ones), whereby the gummo-resinous cover of the grain is dissolved and removed. This removal is necessary on account of the fact that this substance becomes very deep brown, almost blackish, coloured by fermentation of the dough; the grain at the same time absorbs from 65 to 70 per cent of water, and is then reduced to a paste by means of machinery very similar to that used in chocolate mills. This perfectly white paste is next leavened, and after fermentation is ready for baking. By this process, from the same quantity of grain which by the usual process only yields 108 to 110 kilos. of bread, the yield is increased to 145 kilos. of very superior quality and far greater nutritive power; moreover, a very considerable saving of labour and expenses connected therewith is effected by the application of this new process, which has been thoroughly tested by competent and independent scientific as well as practical men.

M. Deligny's process for the preparation of pyrophosphate of lime for agricultural purposes is as follows:—The coprolite, or other native tribasic phosphate, or bone-ash, is first treated with hydrochloric acid, and the mixture thus obtained dried in a reverberatory furnace, leaving a pyrophosphate of lime, which, according to the author, contains 55 per cent of phosphoric acid, while the hydrochloric acid used is—at least in a great measure—recovered. The reaction is based upon the fact observed by the author, that from a mixture of acid phosphate of lime and chloride of calcium, when heated to 100°, the hydrochloric acid is driven off by the acid phosphate, leaving a bibasic phosphate, which is very readily assimilated by plants.

Dr. Louvel has experimented on the large scale on a process of preserving grain, ship-biscuits, and flour, and especially preventing these articles being damaged by insects, rats, and mice, by placing the same into strongly-made iron (boiler-plate) vessels of sufficient capacity to contain 10 cubic metres (27·512 bushels) of grain or flour, and next, after having hermetically closed the man-hole of this vessel, producing a vacuum in it by the aid of an air-pump, it being sufficient for practical purposes that the vacuum be from 10 to 12 centimetres of mercury, that is, a reduction of about from one-sixth to one-seventh of the ordinary atmospheric pressure. The results of these experiments (sufficient time having been amply given to test their real value) is satisfactory in every respect. The cost of the apparatus, including air-pump, gauges, tubing, and fittings, is about £64, but one air-pump can be used for a number of these vessels. It should be observed that the quantity of grain lost or rendered unfit for human food by the ravages of insects, rats, mice, worms, &c., amounts on an average to fully 13 per cent of a crop, while, moreover, by this mode of preserving, much labour required for shovelling grain about in the granaries is rendered unnecessary.

CHEMISTRY.

Dr. S. Meunier states that when a piece of meteoric iron is fixed to the positive pole of a Bunsen battery, the other pole being a piece of silver, and the electrodes are placed in an aqueous solution of bisulphate of potassa, and contact made, there will appear on the iron an iridescent colouration similar to the colouration brought about by heating the polished iron; if no contact takes place, there is produced upon the iron a figure similar to that which acids produce, but by this method it is more readily and more neatly brought out.

Professor J. Lawrence Smith has given a detailed description and analyses of the large masses of meteoric iron in North Mexico, with the description of a new mass—the San Gregorio Meteorite. This immense mass of meteoric iron is situated on the western border of the Mexican desert. Its shape bears some likeness to that of a blacksmith's anvil. Its greatest length is 6 feet 6 inches; it is 5 feet 6 inches high, and 4 feet thick at its base. On one part of its surface "1821" is cut with a chisel, and above this date is the following inscription:—"Solo dios con un poder este fierro destruerâ, por que el en mondo non habra quien lo puedo deschacer" (Only gods can have the power to break up this mass of iron, for there is no body on earth who can break it to pieces). The weight of this mass is nearly 5 tons; it lies near to the spot where it has fallen, but nothing is further known of its history. A small detached specimen of this stone, which is of the softer meteoric iron (sp. gr. = 7·84) gives the following chemical results:—Iron, 95·01; nickel, 4·22; cobalt, 0·51; copper, minute traces; phosphorus, 0·08. The Mexican desert has an extension of 400 miles from east to west, and 500 miles from north to south, equal to an area of 200,000 square miles. The United Kingdom has an area of 121,518 square miles.

In works on chemistry, indigotine (pure indigo blue) is described as a body insoluble in water, alcohol, ether, fatty and essential oils, and dilute acids and alkalies; yet strong and boiling alcohol, and even somewhat more so methylic alcohol (not methylated spirit), dissolve enough indigotine to become blue-coloured, but, on cooling, the greater part of the dissolved substance is thrown down again. By experimenting with phenic acid, M. C. Méhu has found that this substance is an excellent solvent for indigotine, which may be extracted readily and in pure state from indigo, care being taken to wash this latter substance first with water, then with dilute hydrochloric acid, and next several times with boiling alcohol: in order to prevent the solidification of phenic acid on cooling (heat has to be applied to dissolve the indigotine), some camphor may be added to it. With 500 grms. of phenic acid, 2 grms. of indigotine may be readily obtained in one operation, and in very pure well-defined crystals. Indigotine is also soluble, to some extent, in phenic acid when cold, this solution exhibiting a very deep purple colour.

Mr. C. Bullock has published the results of a few experiments to solve approximatively the question, "What amount of acids or alkalies is necessary to give a distinct change of colour to the test-paper?" Blue litmus-paper should be distinctly blue, but not a deep shade, in colour; the directions given by Dr. Fresenius in his "Qualitative Analysis" will afford a sensitive paper. When carefully made it affords the reaction with one drop of acetic acid at 30 per cent in the following quantities of water:—In 4 ozs., it turns red immediately; in 6 ozs., completely red in half a minute; in 10 ozs., changes on the edge in one-fourth minute, and is completely reddened in 1 minute; in 13 ozs., it is completely red in 1½ minutes, and remains red when dry; in 16 ozs. of water the limit of distinct reaction is found. Reddened litmus should have a purple-red colour, and the paper when dry a distinct red colour free from blue. With 1 grain of anhydrous carbonate of soda in 32 ozs. of water the paper turns blue in 1 minute; in 56 ozs., in 3 minutes; in 64 ozs., in 4 minutes; in 80 ozs., in 7 minutes; in 160 ozs. of water the limit of distinct reaction is found; the blue shade can be seen before the colour is dissolved from the paper. In these experiments the paper was submerged in the liquid.

QUARTERLY LIST OF PUBLICATIONS RECEIVED FOR REVIEW.

Index of Spectra. By W. Marshall Watts, D.Sc. With a Preface by H. E. Roscoe, B.A., Ph.D., F.R.S. *Henry Gillman.*

A Synonymic Catalogue of Diurnal Lepidoptera. By W. F. Kirby. *J. Van Voorst.*

The Laws of the Winds prevailing in Western Europe. Part I. By W. Clement Ley. *Edward Stanford.*

Geology of Oxford and the Valley of the Thames. By John Phillips, M.A., F.R.S., F.G.S. *Oxford: Clarendon Press.*

Theory of Heat. By J. Clerk Maxwell, M.A., LL.D., F.R.SS. L. & E. *Longmans & Co.*

A Manual of Zoology for the Use of Students. By Henry Alleyne Nicholson, M.D., &c. Second Edition. Revised and Enlarged. *William Blackwood & Sons.*

Technical Arithmetic and Mensuration. By Charles W. Merrifield, F.R.S. *Longmans & Co.*

A Dictionary of Chemistry. By Henry Watts, B.A., F.R.S. Supplement. *Longmans & Co.*

The Origin of Species by Means of Natural Selection; or, the Preservation of Favoured Races in the Struggle for Life. By Charles Darwin, M.A., F.R.S. *John Murray.*

A Chart of the Northern Hemisphere of an Equal-surface Projection, with a Key-map on the same Projection. By R. A. Proctor, B.A., F.R.A.S.

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Astronomy and Geology Compared. By Lord Ormathwaite. *John Murray.*

Dr. Pereira's Elements of Materia Medica and Therapeutics. Edited by Robert Bentley, M.R.C.S., F.L.S., and Theophilus Redwood, Ph.D., F.C.S. *Longmans & Co.*

A Treatise on the Theory of Friction. By John H. Jellett, B.D. *Macmillan & Co.*

Elementary Natural Philosophy. By J. Clifton Ward, F.G.S. *Trubner & Co.*

Experimental Steam Boiler Explosions. By Professor R. H. Thurston. *Journal of the Franklin Institute.*

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The Year-Book of Facts in Science and Art. By John Timbs. *Lockwood & Co.*

An Elementary Treatise on Curve Tracing. By Percival Frost, M.A. *Macmillan & Co.*

Science Primers—Physics. By Balfour Stewart. *Macmillan & Co.*

Science Primers—Chemistry. By H. E. Roscoe. *Macmillan & Co.*

Monograph of the British Graptolitidæ. By H. Alleyne Nicholson, M.D., &c. *William Blackwood & Sons.*

New Theory of the Figure of the Earth considered as a Solid of Revolution, founded on the Direct Employment of the Centrifugal Force instead of the Common Principles of Attraction and Variable Density. By William Ogilby, M.A. *Longmans & Co.*

Corso di Geologia del Professore Antonio Stoppani. Vol, i., Dinamica Terrestre. *Milano: G. Bernardoni.*

Erratum.—In No. 33, page 9, line 26, for "*quartzose cells*," read "*quartzose celts*."